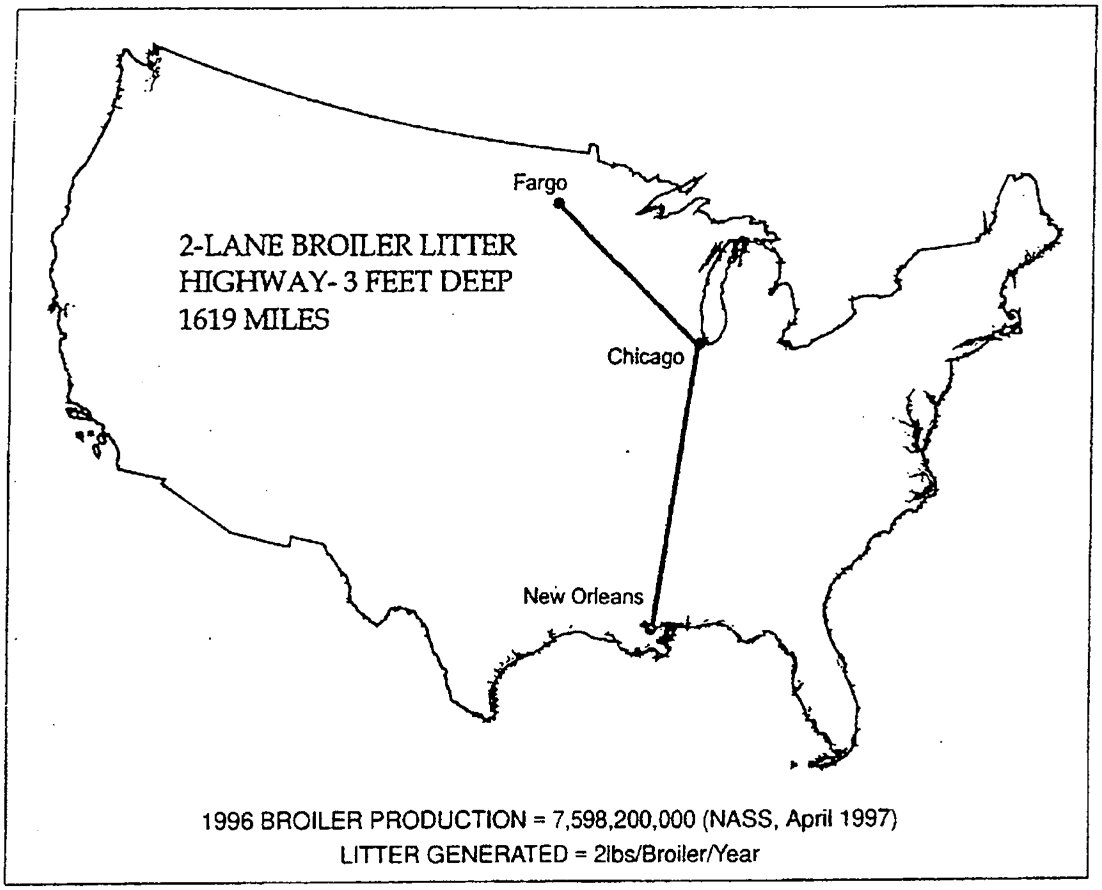

Figure 1.—The broiler litter highway: broiler litter generated in 1996, in the United States.

water. The only way to know for certain its quantity, concentration and composition is from lab analysis. The amount of manure a given flock produces can be estimated from the amount of feed the birds eat. Roughly 20 percent of the feed consumed by poultry is converted to manure. Manure mixed with a bedding material is called litter, and its constituent properties vary, depending on how the chickens are fed and their age and size.

Other conditions that affect litter's quality include the age and type of the bedding material, excessive moisture, frequency of cleanouts, and subsequent storage conditions. The constituents of the litter can be estimated from prior analyses of similar wastes, but all litter should be analyzed at least once a year until its nutrient value is firmly established (after that, it may be tested less frequently, perhaps every two or three years unless management practices change).

The volume of litter varies widely, depending on the producer's management style. Indeed, many of the same conditions that determine the litter's makeup also affect its quantity. For example, the feedstock, number of cleanouts, climatic conditions, and bird genetics are all factors. Broilers, however, produce as much as two pounds of litter per bird or about one ton per year per 1,000 birds: about 81 cubic feet of litter for each 1,000 birds.

In 1996, nearly 15.2 billion pounds of litter were produced by broiler operations in the United States — enough to cover 1,619 miles of a two-lane highway to a depth of three feet. This estimate is from the USDA National Agricultural Statistics Service, and the "litter highway" can be imagined as the distance from New Orleans, Louisiana, to Chicago, Illinois, and on to Fargo, North Dakota (Fig. 1).

That much litter can and must be responsibly used. Bedding materials, manure, and used

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erals in broiler litter include calcium, magnesium, sulfur, sodium, iron, manganese, zinc, and copper.

Table 1.—	
LITTER PRODUCED PER 1,000 BIRDS	
2 lb bird	0.45 ton per cycle
4 lb bird	1.0 ton per cycle
6 lb bird	1.5 ton per cycle
AVERAGE NUTRIENT CONTENT OF BROILER LITTER	
nitrogen	60 lb per ton
P_2O_5	55 lb per ton
K_2O	45 lb per ton

Management Practices

Litter should be kept from becoming overly wet. In a well-managed house, the moisture level in litter will range from 25 to 35 percent. Higher moisture levels increase its weight and reduce its nitrogen value. Litter that does not become saturated can be left in the house between flocks. However, cake (litter that is saturated with water) must be removed from the house between cleanouts to protect the remaining litter. After its removal, the cake should be dried to prevent odor, precautions should be taken to prevent groundwater contamination, and stormwater should be diverted from contact with the litter.

If cake is properly removed from the house, total cleanouts can be delayed — sometimes for an entire year. Checking for water leaks in the house and keeping the house at an even temperature are management practices that reduce the production of cake. The total weight and volume of litter will depend on the type of bedding material used, its depth, whether cake is present or removed, and the length of time between cleanouts. Its quality also depends on how it is removed from the house, whether the floor is raked or stirred between flocks, and how it is stored.

Manure is dried by aerating it using some form of ventilation. Ventilation can be achieved naturally (through proper housing design) or mechanically (through equipment). Aeration should produce a low odor product with about 15 to 25 percent moisture. Because it has less odor and weight, it is less expensive to haul, contains more nutrients, and is easier to store.

Dry Waste Storage Facilities

Common procedures for managing dry broiler litter or dry manure from layer operations center on protecting this material after it is removed from the house until its valuable fertilizer nutrients can be put to other uses. Litter that is not properly stockpiled or stored suffers a reduction of nitrogen from releases to air and water. These losses represent both lost income and the potential for surface and groundwater contamination. To prevent such losses, facilities used for storing dry poultry waste should meet or exceed the following conditions:

- a sufficient capacity to hold the waste until it can be applied to land or transported off the farm,
- adequate conditions of temperature and humidity to permit storage of the waste until it is needed,
- a concrete or impermeable clay base to prevent leaching to groundwater,
- appropriate roofing, flooring, and drainage to present rainfall, stormwater, runoff, and surface or groundwater from entering the waste,
- a location that prevents runoff to surface waters or percolation to groundwater, and
- ventilation and containment for effective air quality and nuisance control.

The ideal storage design is a roofed structure with an impermeable earthen or concrete floor. This design keeps the litter dry, uniform in quality, and easy to handle, and it also minimizes fly and odor problems. Management plans that allow for proper storage achieve the following:

- save water,
- improve bird quality,
- improve the production environment,
- reduce the amount of ammonia released from litter,
- reduce the volume of cake,

- extend the time between cleanouts,
- increase the product's value and flexibility, and
- protect the quality of adjoining waters.

Kinds of Storage Facilities

Generally, storage facilities can be open, covered, or lined (permanently lined, in some cases); or they can be bunkers or open-sided buildings with roofs. Perhaps the most common facilities for collecting and storing poultry litter include floors, pits, dry-stack buildings, or covered outdoor storage facilities with impermeable earthen or concrete flooring.

Floor Storage

Most broiler, roaster, Cornish hen, pullet, turkey, and small layer operations raise birds on earthen or concrete floors covered with bedding material (Fig. 1). A layer of wood shavings, sawdust, chopped straw, peanut or rice hulls, or other suitable bedding material is used as a base before birds are housed. Wet litter — that is, cake — is removed after each flock. A complete clean-out can be done after each flock or once every 12 months or longer, depending on the producer's requirements. Slat or wire floor housing, used mainly for breeder flocks, can be handled the same way. Floor storage is the most economical method to store litter. Care must be taken not to leave foreign material such as wire, string, light bulbs, plastic, or screws in the litter.

Dry Stack Storage

Temporary storage of litter in a roofed structure with a compacted earthen or concrete floor is an ideal management method (Fig. 2). Large quantities of waste can be stored and kept dry for long periods of time. To prevent excessive heating or spontaneous combustion of wastes, stacks should not exceed 5 to 8 feet and large variations in moisture content should be avoided. Dry stacks promote ease of handling and uniformity of material; in addition, disposal is relatively easy. Dry stacks protect the resource from bad weather and make it available for distribution at appropriate times.

A variation on this option is a stack or windrow located in an open, well-drained area and protected from stormwater runoff. The stack must be covered with a well-secured tarpaulin or other synthetic sheeting.

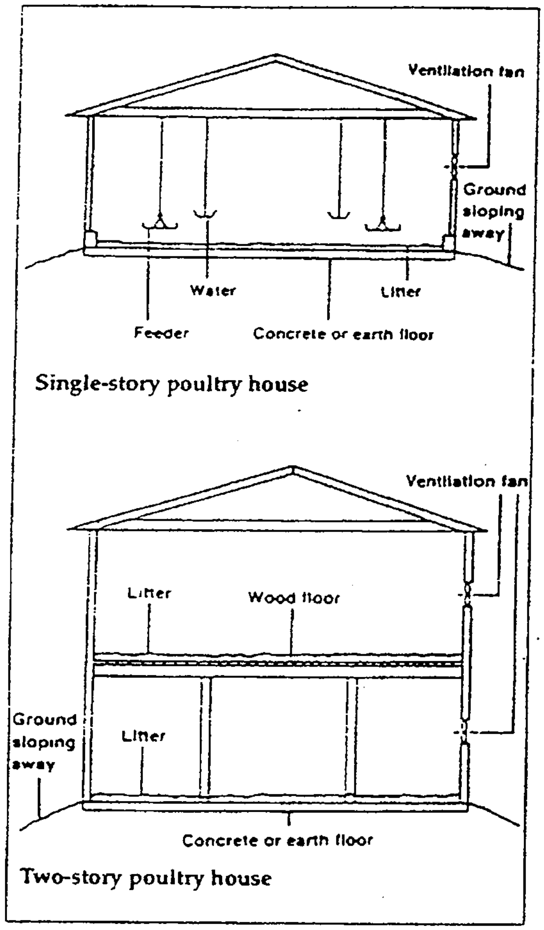

Figure 1.—Two types of litter-floor poultry houses.

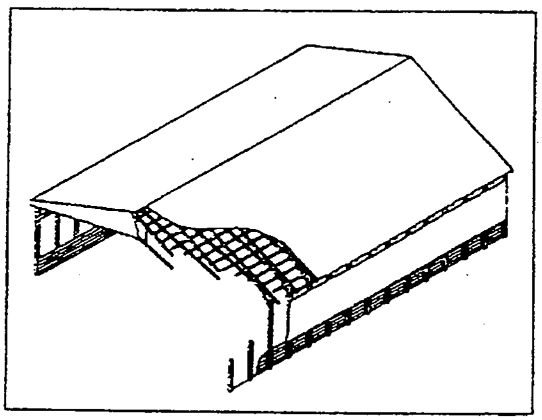

Figure 2.—An ideal dry stack storage facility is a roofed structure with an earthen or concrete floor.

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Storage in covered or uncovered facilities is not the only alternative. Field storage on the farm, applicator storage (that is, storage by the crop farmer who will use the litter or manure for fertilizer), cooperative storage (several growers sharing a larger facility off-site), and private storage (by entrepreneurs who will sell or process the litter to create new products) are additional methods of waste storage. Each method must be evaluated in terms of cost, environmental safety, and industry and regulatory practice.

In some states, permits may be required for a storage facility or for other parts of your resource management system. Possible zoning restrictions may also influence your choice of storage systems.

Proper storage is essential to optimize the waste's fertilizer value for crops, provide ease of handling, and avoid groundwater or surface water contamination. Consider also the feasibility of processing alternatives. Waste can be

- composted and pelletized to produce soil amendment and fertilizer products,
- converted to feed for beef cattle or to briquettes for fuel, or
- deposited in lagoons for anaerobic digestion and methane production.

Above all, use soil and manure testing to improve the success (crop yields) and timing of land applications. Practice biosecurity (that is, safeguard the application from disease causing organisms and fly larvae) at all times.

Using poultry litter as a feed supplement for cattle has become popular. Methods of waste handling and storage can greatly affect the quality of the material as a feed ingredient. Litter with the highest nutritional value for refeeding is found in the upper layers of the litter pack. Large amounts of soil increase the ash content and reduce the nutritive value of litter. Feed litter should be deep stacked at least three weeks to ensure that sufficient heat is generated to kill pathogens.

> Remember: The use of manure storage structures is a best management practice for the protection of environmental quality, and an interim step in waste management planning. It should be followed by nutrient management planning and appropriate use of the litter for land application.

References

Brodie, H.L., L.E. Carr, and C.F. Miller. 1990. Structures for Broiler Litter Manure Storage. Fact Sheet 416. Cooperative Extension, University of Maryland, College Park.

Boles, J.C., K. VanDevender, J. Langston, and A. Rieck. 1993. Dry Poultry Manure Management. MP 358. Cooperative Extension Service, University of Arkansas, Little Rock, AR.

Boles, J.C., G. Huitink, and K. VanDevender. 1993. Utilizing Dry Poultry Litter — An Overview. FSA 8000-5M-7-95R-5563. Cooperative Extension Service, University of Arkansas, Little Rock, AR.

Cabe Associates, Inc. 1991. Poultry Manure Storage and Process: Alternatives Evaluation. Final Report. Project Number 100-286. University of Delaware Research and Education Center, Georgetown.

Department of Natural Resources and Environmental Control and Cooperative Extension Service. 1989. Poultry Manure Management: A Supplement to Delaware Guidelines. University of Delaware, Newark.

Donald, J. 1990. Litter Storage Facilities. DTP Circular 10/90—004. Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Donald, J.O., and J.P. Blake, F. Wood, K. Tucker, and D. Harkins. 1996. Broiler Litter Storage. Circular ANR-839. Alabama Cooperative Extension Service, Auburn and Alabama A&M Universities, Auburn, AL.

Georgia Soil and Water Conservation Commission. 1994. Planning Considerations for Animal Waste Systems for Protecting Water Quality in Georgia. In cooperation with USDA Natural Resources Conservation Service and U.S. Environmental Protection Agency, Athens, GA.

Payne, V.W.E., and J.O. Donald. 1991. Poultry — Waste Management and Environmental Protection Manual. Circular ANR-580. Alabama Cooperative Extension Service, Auburn, AL.

Vest, L., and B. Merka. 1994. Poultry Waste: Georgia's 50 Million Dollar Forgotten Crop. I-206. Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Science, Athens, GA.

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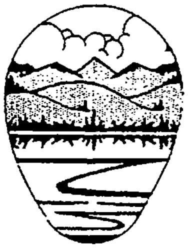

Liquid Waste Management

Ducks, geese, and some layer operations are usually handled through liquid waste management systems, though water greatly increases the amount of waste to be processed. In liquid waste management systems, collection and storage are generally combined in one operation, and in facilities that include pits, settling tanks, and earthen storage ponds, or lagoons. Sometimes additional treatment is used to convert its nutrient and mineral content to more stable products.

Volume comparisons between liquid and dry manure show that 10,000 caged layers produce nearly 2,500 pounds of manure per day, with an estimated volume of 50 cubic feet. In dry form, this manure weighs about 695 pounds, with 10 percent moisture, and reaches a volume of 27 cubic feet. This difference not withstanding, liquid waste management systems can be easier to automate and less labor intensive than dry waste management.

Constraints on the management system appear to be greater when the system is liquid:

- ▼ the pond or other holding facility must be emptied immediately when it is filled — the grower has less flexibility for scheduling land applications;
- ▼ if the waste storage structure is not properly designed and sealed, its contents may leach to groundwater or overflow into ditches, agricultural drains, or other surface water resources;
- ▼ toxic gases or unpleasant odors can occur in liquid waste, particularly when it is agitated or stirred;
- ▼ flies may find the manure storage ponds attractive breeding grounds, especially if they are improperly managed; and — a more important consideration —
- ▼ nearly all states have clean water laws that prohibit wastewater discharges to surface waters and groundwater recharge areas. Therefore, nearly all animal operations that have a liquid waste management system must have formal or informal permits to comply with these laws, even if they are not required to file for federal National Pollution Elimination Discharge System permits.

By contrast, solid waste systems are perceived to have less environmental risks; and with less volume to control, they may also have lower equipment and energy costs. These considerations — and operator preference — may help growers decide between dry and liquid waste management systems.

Lagoon flush systems were a source of environmental and public relations problems (e.g., spills and odors) during heavy rains in 1995 and 1996. If such problems persist, growers and researchers are likely to combine the best features of liquid and dry systems to find more protective and efficient methods of waste management. Researchers in Georgia have already modified a flush-type system beneath a caged layer line to accommodate a deep litter composting system. Plywood boxes containing plywood shavings are placed under the cages to collect the manure, which is turned twice weekly to promote composting.

Liquid Collection Methods — Pit Storage

Layers or pullets are often raised in cages arranged in two to four decks. The manure falls directly into a pit or is scraped into the pit from intervening dropping boards. Pits must be cleaned regularly, and the manure stored in concrete or steel storage tanks or applied directly to the land. A lagoon may be necessary to catch overflow. Ventilation fans are essential to keep the manure dry, and reduce toxic gases, fly problems, and offensive odors.

There are three basic pit designs:

- **Shallow-pit systems,** built of concrete at ground level, are 4 to 8 inches deep and located 3 to 6 feet below the cages. Manure is scraped from the pit or flushed out with water and collected in a storage area or loaded directly into a spreader (Fig. 1).

- **Deep-pit systems** are usually 4 to 8 feet wide and may extend 2 to 6 feet below ground level with the cages at least 8 feet above the concrete or masonry floor. The pit floor and sidewalls must be sealed and thoroughly protected from stormwater runoff and groundwater seepage. Foundation drains and external grading are needed to remove subsurface water and to drain surface water away from the building.

- **High-rise systems** are similar to deep-pit systems but are built entirely aboveground. The cages are 15 to 30 feet above the ground (Fig. 2). The pit floor should be concrete and graded, with foundation drains. The water supply must be controlled if the wastes are retained in place for extended periods. If outside water penetrates the system and breaks out the side board, the manure can develop a serious fly problem or leach nutrients to groundwater.

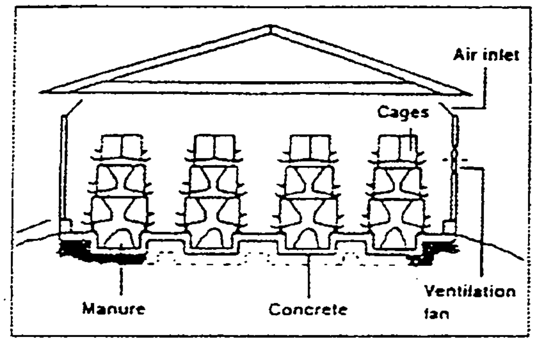

Figure 1.—Shallow-pit poultry house with cages.

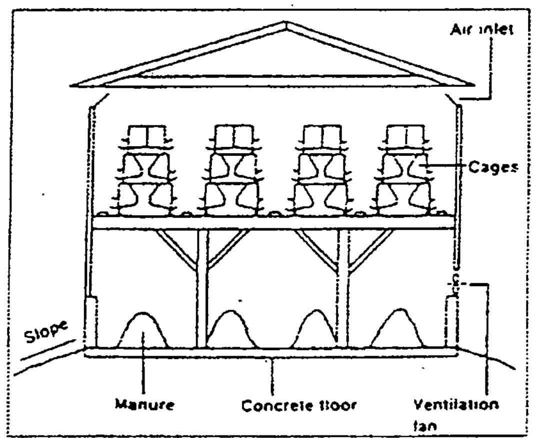

Figure 2.—High-rise poultry house with cages.

Settling Tanks

Concrete, concrete block, or steel storage tanks can be used to collect solids and to skim floating material from a layer operation. A floating baffle or other separator can be installed to remove egg shells, feathers, and other debris. The tank should be placed between the layer house and a waste storage pond or lagoon. Normally, a settling tank is 4 feet at the deep end, sloping to ground level. Walls are slotted to allow drainage of the settled waste.

It is recommended that two settling tanks be installed; one can be drained and cleaned while the other remains in operation. The tanks must be properly constructed and sealed to prevent groundwater or surface water pollution. In tanks and storage ponds, unpleasant odors and dangerous gases may be present and may require protective measures.

Treatment Lagoons and Ponds

Semisolid or liquid manure can be removed from the pits (by flushing or scraping) and stored in below- or aboveground storage tanks, steel storage tanks, or holding ponds. Lagoons, a type of earthen storage basin, have a manure treatment function in addition to a storage function. Lagoons use anaerobic or aerobic bacteria to decompose the waste, and they can even be used as digesters to convert large masses of waste into gases, liquids, or sludge.

Lagoons are easy to manage, convenient, and cost-efficient. Storage and land application can be handled more opportunely if the grower has a lagoon, and labor costs and operating costs are slight after the initial investment. Such facilities became a somewhat popular component of waste management systems during the 1970s when the interest shifted from simply using waste for fertilizer in land applications to treating the waste to produce a more convenient waste management system overall (with less organic content to land apply).

The decomposition process will be anaerobic or aerobic. Anaerobic bacteria in animal waste (i.e., bacteria that live in animal intestines) cannot work in the presence of oxygen. Aerobic bacteria, on the other hand, must have oxygen; therefore, anaerobic lagoons are deep and airless; aerobic lagoons are spread over a large surface area, take in oxygen from the air, and support algae. Both aerobic and anaerobic lagoons provide storage and disposal flexibility.

Other factors, however, must also be considered. Anaerobic lagoons are a source of odors and nitrogen losses and may require frequent sludge removal if they are undersized. Groundwater protection may be difficult to secure in either system. If mechanical aeration is used for an aerobic system, energy costs must be included in the accounting. Proper management is essential for lagoon maintenance and operation.

Aerobic Lagoons

The design, shape, size, capacity, location, and construction of the lagoon depends on its type. Aerobic lagoons require so much surface area (to maintain sufficient dissolved oxygen) that they are an impractical solution to most waste management problems. They may require 25 times more surface area and 10 times more volume than an anaerobic lagoon. Nevertheless, some growers may consider using an aerated lagoon — despite its expense — if they are operating in an area highly sensitive to odor.

Some of the sizing difficulty can be solved by using mechanical aeration — by pumping air into the lagoon — but the energy costs for continuous aeration can be high. Aerobic lagoons will have better odor control, and the bacterial digestion they provide will be more complete than the digestion in anaerobic lagoons.

Lagoon design and loading specifications should be carefully followed and monitored to increase the effectiveness of the treatment. No more than 44 pounds of biological oxygen demand (BOD) should be added to the lagoon per day per acre. The lagoon should have sufficient depth so that light will penetrate the 3 or 4 feet of water. Effluents from the lagoon should be land applied to avoid long-term ponding and to make economical use of the nutrients that remain in them.

Anaerobic Lagoons

Anaerobic treatment lagoons are earthen basins or ponds containing diluted manure that will be broken down or decomposed without free oxygen. In the process, the organic components or BOD in the manure will be liquified or degraded naturally.

Anaerobic lagoons must be properly designed, sized, and managed to be an acceptable animal waste treatment facility.

Liquid volume rather than area determines the size of anaerobic lagoons. The lagoon should accommodate the design treatment liquid capacity and the amount of wastewater to be treated; it should also have additional storage room for sludge buildup, temporary storage room for rain and wastewater inputs, extra surface storage for a 25-year, 24-hour storm event, and at least an additional foot of freeboard to prevent overflows.

The design criteria for anaerobic lagoons are based on the amount of volatile solids to be loaded each day. The range is from 2.8 to 7.0 pounds of volatile solids per day per 1,000 cubic feet of lagoon liquid. The amount of rain that would collect in a 24-hour storm so intense that its probability of happening is once in 25 years requires at least 5 to 9 inches of surface storage, although the actual volume of surface storage required is site specific.

To protect the groundwater supply, lagoons should not be situated on permeable soils that will not seal, on shallow soils, or over fractured rock. The bottom of the lagoon should not be below the water table. Nor should mortalities be disposed of in lagoons. In fact, screening the wastes before they enter the lagoon helps ensure complete digestion and the quality of the wastewaters for land applications. If the site's topography indicates a potential for groundwater contamination, then any earthen basin should be lined with clay, concrete, or a synthetic liner.

New lagoons should be filled one-half full with wastewater before waste loading begins. Planning start up in warm weather and seeding the bottom with sludge from another lagoon helps to establish the bacterial population. Because bacterial activities increase in high temperatures, lagoons, in general, work best in warm climates. Manure should be added to anaerobic lagoons daily, and irrigation (drawdown) should begin when the liquid reaches normal wastewater maximum capacity. The liquid should not be pumped below the design level treatment, however, because the proper volume must be available for optimum bacterial digestion.

Drawdown (that is, the lagoon liquid) can be used for land applications guided by regular nutrient management planning and sampling of the lagoon liquids and soils to ensure safe and effective applications. When sludge accumulation diminishes the lagoon's treatment capacity, it, too, can be land applied under strictly monitored conditions.

Secondary lagoons are often needed for storage from the primary lagoon. Using a secondary lagoon for irrigation also bypasses some of the solids picked up in the primary lagoon. The size of secondary lagoons is not critical.

Information and technical assistance and some cost-share programs are available for producers who determine that a lagoon system should be part of their resource management system. The USDA Natural Resources Conservation Service (NRCS) and the Cooperative State Research, Extension, and Education Service offices can provide additional assistance.

Land Applications

Land application of liquid waste can be achieved with a manure slurry or irrigation system. If the application falls directly on the crop, care must be taken to prevent ammonium toxicity and burning. Because raw manure contains high amounts of uric acid, it should be thoroughly mixed before application. Layer lagoon sludge is more dense than a pullet lagoon sludge because of its high grit or limestone content and should be diluted before application.

Timing is a major factor in successful land applications. There should be no land application prior to, during, or immediately following a rainfall event. The manure must also be uniformly applied — whether you are using a manure spreader or an irrigation system. The operator should be particularly careful (especially during a drought) not to coat the plants with lagoon liquid. Instead, make several small applications of lagoon liquid, rather than one large one.

Liquid waste is primarily disposed of through land applications. Proper spreading on the land is an environmentally acceptable method of managing waste. However, with increasing environmental concerns and the need to match closely the fertilizer needs of crops, farmers can no longer afford to simply "spread manure."

The USDA NRCS, Cooperative State Research, Extension and Education Service, and other agencies offer poultry waste and nutrient management planning assistance. These offices have worksheets to help growers plan liquid waste management, which includes the following tasks:

- ▼ determining the amount and volume of waste generated;
- ▼ calculating land application requirements;
- ▼ sampling and analyzing the nutrient composition in poultry litter, manure, or slurry; and
- ▼ matching the nutrients available in these products with crop nutrient requirements for land applications.

Detailed information on how to prepare nutrient assessments, conduct soil testing, and calculate application rates, timing, and methods of application are also available from these agencies.

The use of nutrient management planning will help growers make economical and practical use of the organic resources generated on their farms.

References

Barker, J.C. 1990 rev. Lagoon Design and Management for Livestock Waste Treatment and Storage. Agri-Waste Management. EBAE-103-83. North Carolina Agricultural Extension Service. Agricultural and Technical State University of North Carolina, University Station.

Brodie, J.L., L.E. Carr, and C.F. Miller. 1990. Structures for Broiler Litter Manure Storage. Fact Sheet 416. Cooperative Extension Service, University of Maryland, College Park.

Fulhage, C. 1993. Land Application Considerations for Animal Wastes. WQ202. University Extension, University of Missouri, Columbia.

Merka, W.C., and S.A. Thompson. 1997. Deep Litter Composting as a Means for Retrofitting Lagoon Flush Systems. Abstract. Presentation at the 18th Annual Meeting of the Southern Poultry Science Society and the Southern Conference on Avian Disease. World Congress Center, Atlanta, GA.

Michigan Agriculture Commission. 1991. Generally Accepted Agricultural Practices for Manure Management and Utilization. Lansing, MI.

Payne, V.W.E., and J.O. Donald. 1991. Poultry Waste Management and Environmental Protection Manual. Circular ANR 580. Cooperative Extension Service, Auburn, University, Auburn, AL.

Ritter, W.F. No date. Poultry System Design and Management for Environmental Protection. University of Delaware, Newark.

U.S. Department of Agriculture. 1992. National Engineering Handbook 210, Part 651. *In* Agricultural Waste Management Field Handbook. Soil Conservation Service, Washington, DC.

U.S. Department of Agriculture. 1993. Agricultural Waste Management Handbook. Part 651. Soil Conservation Service, Washington, DC.

Watson, H. 1990. Liquid Manure Handling Systems. DTP 12/90-018. Alabama Cooperative Extension, Auburn University, Auburn, AL.

Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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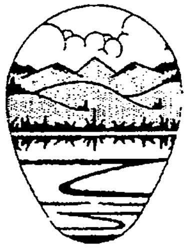

Composting Waste Products

Poultry litter or layer manure is most often land applied to pastures and crops for its value as an organic fertilizer. We know from long experience how beneficial this practice can be when soil and manure nutrient testing are integrated with crop nutrient needs to determine the amount and timing of the application. This integration makes it possible to approach land application as a wise use of resources rather than as a disposal method.

Proper storage and treatment of poultry by-products (litter, manure, hatchery waste, and dissolved air flotation [DAF] skimmings) before use are important to minimize compositional changes and decrease odor and handling problems. Depending on the by-product, dry storage, ensiling, or composting may be appropriate treatments. Resource management systems may include incineration and burial as methods of disposal; however, these techniques are not called treatments because they do not usually provide any reusable products.

Composting is an environmentally sound and productive way to treat poultry by-products and mortalities (see also PMM/4 and PMM/5). The product of composting is easier to handle, has a smaller volume, and is a more stable product than the raw materials. The nutrient content of the compost will be nearly the same as the starting materials if the composting is performed properly.

While compost can be land applied to decrease the need for nutrients from commercial fertilizers, composted by-products may also be marketed for higher value uses on turf, for horticultural plant production, and in home gardening landscaping. It can be added as an amendment to soils for transplanting flowers, trees, and shrubs, or to establish new lawns. Compared to commercial fertilizers, poultry by-product compost will have a lower nutrient analysis (e.g., 2-2-2) for nitrogen, phosphorus, and potassium. However, there are other benefits to the soil and plant growth associated with the organic matter and micronutrients in compost.

Understanding the Process and Benefits of Composting

Composting is a natural, aerobic, microbiological process in which carbon dioxide, water, and heat are released from organic wastes to produce a stable material. Leaves and other organic debris are subject to this process all the time — that is, the activity of microorganisms transforms these materials into a soil-like, humus-rich product.

This natural process can also be used as a resource management technique to transform large quantities of litter, manure, and other poultry by-products into compost. The conditions under which natural composting occurs can be stimulated and controlled so that the materials compost faster and the nutrient value of the compost is maximized.

The composting process is relatively simple:

1. By-products, for example, litter, manure, eggshells, hatchery waste, and DAF skimmings, are placed in bins, piles, or elongated piles called windrows. A bulking agent or carbon amendment (e.g., sawdust, wood chips, yard waste, or paper that is rich in carbon but low in other nutrients) is usually necessary to provide the proper ratio of carbon to nitrogen in the mix and to improve aeration.

2. Air is needed to support and enhance microbial activity. Because the composting microorganisms are aerobic, that is, oxygen using, the windrows and compost piles must be aerated to ensure the

efficiency of the process. Sufficient aeration also minimizes the formation of objectionable odors that form under anaerobic (oxygen depleted) conditions. Adequate aeration can be provided by forced air systems, such as blowers or fans; or by turning the compost with a front-end loader or a commercially available compost turner as required.

3. Mechanical agitation or turning of the materials supplies aeration, helps mix the materials, and distributes any added water.

4. Temperatures in the compost must be maintained at levels above approximately 130°F to kill any pathogens (disease-causing organisms) and promote efficient composting. Temperatures above 150 to 160°F should be avoided because they reduce the microorganisms that are beneficial to the composting process.

5. Adequate moisture, between 50 and 60 percent, is necessary for optimal microbial activity.

Handling Compost

Compost produced from poultry by-products can be used in many different ways: it can be used directly as a soil amendment for agricultural or horticultural uses; pelletized or granulated for ease of transportation and application; or enhanced with conventional fertilizers to improve its nutrient value.

Even though composting is a relatively new manure management technology, the off-farm market is clearly growing. Consumer awareness of the safety and convenience of the product is beginning to penetrate the market. Current limiting factors are growers' unfamiliarity with marketing strategies and competition from less costly products.

Possible Drawbacks

Composting, like any management technique, cannot be undertaken lightly, whatever its benefits. It requires a commitment of time and money for equipment, land, storage facilities, labor, and management. Composting is an inexact process that depends heavily on the quality and characteristics of the materials being composted and the attention given to the composting process.

Although the finished product should have no odor or pest problems, such problems may occur during the composting process. Weather may also affect the process adversely. Compost releases nutrients slowly — as little as 15 percent of the nitrogen in compost may be available during the first year of application. In addition, costs associated with production-scale composting can be significant, and federal and state regulations for stormwater runoff from the composting site must be followed.

Despite these potential drawbacks, composting on the farm is a practical resource management technique. Good management will consider every opportunity to eliminate or reduce the concerns associated with composting while maximizing its benefits. Once it is realized that composting can be more than a "dump it out back and forget it" procedure, the technique can be used and adjusted to meet by-product management needs.

Composting Methods

There are four general methods of composting: passive composting, windrows, aerated piles, and in-vessel composting.

▼ **Passive composting** is the simplest, lowest cost method. It requires little or no management because the materials to be composted are simply stacked into piles and left to decompose naturally over a long time.

Passive composting is not suitable for the large quantities of litter or manure produced on poultry farms. It occurs at comparatively low temperatures and decomposition occurs at a slow rate. Anaerobic conditions resulting from insufficient aeration can result in objectionable odors.

▼ **Windrow composting** occurs in long narrow piles that can vary in height and width depending on the materials and equipment available for turning.

For most efficient composting, windrows are turned as required depending on temperature and oxygen measurements.

Windrow composting (Fig. 1) is usually well suited to poultry farms. In this method, the windrows are formed from the material to be composted, water, and any bulking agent or carbon amendment. The piles can range from 3 feet high for dense materials to as high as 12 feet for lighter, more porous materials like leaves. If the piles are too large, anaerobic conditions can occur in the middle; if they are too small, insufficient heat will be maintained for pathogen reduction and optimum microbial activity.

The windrows are turned periodically to add oxygen, mix the materials, rebuild porosity (as the mixture settles), release excess heat, and expose all materials equally to the high interior heat that kills pathogens. Turning can be labor and equipment intensive depending on the method used. In the beginning, it may be necessary to turn daily or even several times a day to maintain sufficient oxygen levels; however, turning frequency declines with the windrow's age.

In addition to needing space for the windrows, the producer will also need turning equipment, a source of water, a dial thermometer, and perhaps an oxygen meter. The turning equipment (Fig. 2) can be front-end loaders, manure spreaders with flails and augers to provide good mixing, or specialty machines. Often older, unused farm equipment, for example, an old potato plow and a farm tractor, can be used for turning compost.

Temperatures within the windrow are most commonly used to determine when turning is necessary. Low temperatures and odors are signs that more oxygen is needed, while cool or hot spots at intervals along the windrow indicate that the material needs to be mixed. During fly season, all windrows should be turned at least weekly. In the winter, windrows can be combined to conserve heat as they diminish in height. Composting time can vary from weeks to months depending on the material being composted, the attention given to composting conditions, and the quantity of material composted.

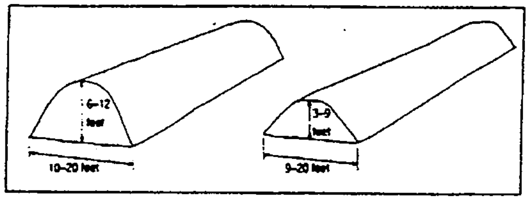

Figure 1.—Typical windrow shapes and dimensions.

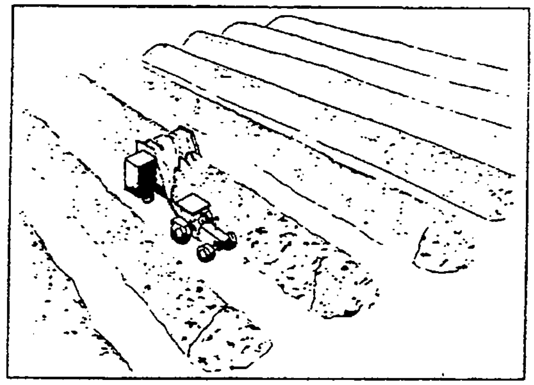

Figure 2.—Windrow composting with an elevating face windrow turner.

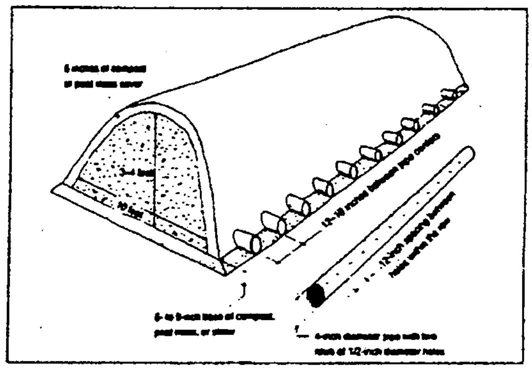

Figure 3.—Passively aerated windrow method for composting manure.

▼ Aerated static composting eliminates the labor of turning the compost by using perforated pipes to introduce air into piles or windrows.

Air can be supplied passively, or with blowers to force air into or through the composting material.

Passively aerated windrows (Fig. 3) are a modification of windrow composting that eliminates turning. In a commonly used system, the windrow is placed on a base of wood chips, straw, or peat, and perforated aeration pipes are added on top of this base. The material to be composted must be very well mixed, since it is not turned, and the windrow should not be higher than 3 to 4 feet. This method has the advantage of minimizing odors and helping to conserve nitrogen.

Aerated static piles or windrows add blowers to the aeration pipes. This method allows larger piles or windrows and permits more efficient composting than passively aerated static piles. Air can either be drawn into or forced through the composting material. The blowers may be controlled to turn on at set intervals or in response to temperatures in the pile or windrow.

▼ **In-vessel composting** is similar to aerated methods but the materials to be composted are contained in bins or reactors that allow for control of aeration, temperature, and mixing, in some systems.

In-vessel composting is actually a combination of methods that involve both aeration and turning. The advantages of in-vessel composting include the elimination of weather problems and the containment of odors. In addition, mixing can be optimized, aeration enhanced, and temperature control improved.

The simplest form of in-vessel composting is bin composting, which is readily adaptable to poultry farms. Bins may be plain structures with wood slatted floors and a roof, conventional grain bins, or bulk storage buildings. Other types of in-vessel composters use silos in which the air goes in at the bottom and the exhaust is captured for odor control at the top; agitated bed systems; and rotating drums. Costs for equipment, operation, and maintenance for a large quantity of materials are high for in-vessel composting.

Factors to consider in choosing a composting method are speed, labor, and costs. Windrows are common on farms; they can use existing equipment, no electricity is required (so they can be remotely located), and they produce a more uniform product. They are, however, also labor intensive and at the mercy of the weather. Adding a paved or compacted clay surface and a simple open-sided building can minimize weather problems and the impact of composting on water quality.

For more information, technical assistance, and possible cost-share programs that may be available to help you begin a composting operation, contact your local conservation district office, the USDA Natural Resources Conservation Service, or the Cooperative State Research, Extension, and Education Service.

References

Biocycle. 1991. The Art and Science of Composting. The JG Press, Inc., Emmaus, PA.

Cabe Associates, Inc. 1991. Poultry Manure Storage and Process: Alternatives Evaluation. Final Report. Project Number 100-286. University of Delaware Research and Education Center, Georgetown.

Carr, L.E. 1997. Composting Poultry Litter. Congressional Animal Waste Conference. Longworth House Office Building, Washington, DC

Carr, L.E., R.C. Moore, and C.A. Johnson. 1992. Composting Dissolved Air Flotation Skimmings from Poultry Processing. ASAE Paper 92-6016. International Summer Meeting of the American Society of Agricultural Engineers, Charlotte, NC.

———. 1992. Hatchery Waste Composting. Proceeding of the 1992 National Poultry Waste Management Symposium. Sheraton Civic Center Hotel, Birmingham, AL. ISBN 0-9627682-6-3, pp. 139-144.

Donald, J.O., C.C. Mitchell, and C.H. Gilliam. 1990. Composting Agricultural Wastes in Alabama. ANR Circular 572. Cooperative Extension Service, Auburn University, Auburn, AL.

Rynk, R., editor. 1992. On-farm Composting Handbook. NRAES-54. Cooperative Extension. Northeast Regional Agricultural Engineering Service. Ithaca, NY.

Smith, B. 1993. Composting and Uses for Manure. Presentation. 1993 Waste Management and Water Quality Workshop. Southeastern Poultry and Egg Association, Atlanta, GA.

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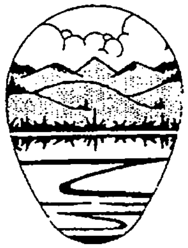

Putting Nutrient Management to Work

Land application, especially field spreading, is in most cases the best use of poultry wastes. It recovers nutrients that would otherwise be lost, improves yield, and reduces the possibility of releasing this material to water and the environment.

Where land is available, manure applications can be substituted for commercial fertilizers, reducing the farmers' costs and helping them comply with environmental laws. At the same time, land applications tend to use the largest amount of waste closest to the point of production.

To ensure that nutrients in waste are not overapplied to the land, the waste must be analyzed for the amount and type of nutrients it contains and the timing of applications must be adjusted to ensure that growing plants can use the nutrients. To accomplish this outcome, the litter should be uniformly applied at the recommended rate. The management practice that offers this assurance is nutrient management planning.

Nutrient management planning as a preliminary to land application has become a standard practice for recovering and using the nutrients in solid and liquid animal waste. It is, like composting, a centuries-old practice, which modern technology has substantially improved. The improvement — in a word — the ability to plan exactly how much manure should be applied — was highly recommended in the early 1990s. In 1995, the poultry industry in the Commonwealth of Virginia announced the decision of its four major integrators to require all new producers to have nutrient management plans. Nutrient planning has since become a requirement in many states.

What Is a Nutrient Management Plan?

Nutrient management planning matches the nutrient needs of the plants and soil with the nutrient contents in the manure to achieve a proper nutrient balance. An effective nutrient management plan consists of the following core components:

- farm and field maps,
- realistic yield expectations for the crops to be grown,
- a summary of the nutrient resources available (the results of soil tests and nutrient analyses of manure, sludge, or compost),
- an evaluation of field limitations based on environmental hazards or concerns (e.g., sinkholes, land near surface water, highly erodible soils, steep slopes),
- application plans based on the limiting nutrient,
- plans that include proper timing and application methods (avoid application to frozen soil and during periods of leaching or runoff), and
- calibration of nutrient application equipment.

Experience will continue to refine this practice. For example, nutrient management is very often based on nitrogen as the limiting nutrient. Nitrogen is a challenging nutrient to manage; it is highly mobile, easily dissolving in runoff and leaching through soil. Phosphorus, on the other hand, is less mobile so it is less likely to move off-site. Buffer zones and filter strips are also planted at the edge of fields and around water resources — to protect them from both nitrogen and phosphorus.

Now, however, soil tests and soil performance are showing relatively high phosphorus levels even in areas that have not been traditionally high in phosphorus. In some cases, these levels are so high that phosphorus must now be used as the limiting nutrient; in other cases, the levels are so excessive that no phosphorus should be applied, perhaps for a very long time. And while buffer strips are helpful, they are not sufficient to reduce phosphorus to acceptable levels.

These conditions notwithstanding, phosphorus is an essential element in bird nutrition. Are we then facing a dilemma? If we go carefully into these new areas, probably not. The solution may be found in enzyme treatments or food additives. Many growers have shown that putting the enzyme phytase in the diet can help maintain bird health and reduce the amount of phosphorus in litter. Phosphorus reductions can also be achieved by treating litter and field soils with alum. As alum treatments also reduce ammonia volatilization, growers are once again provided with a key management notion: good waste management, bird nutrition, and maintaining good management practices year-round are interrelated.

The USDA Natural Resources Conservation Service and Cooperative State Research, Extension, and Education Service offices have prepared tables of the mean average amounts of key nutrients found in different kinds of manure (Table 1). These tables may be used to estimate the nutrient content of your waste source or stockpile. However, as this resource is produced and used under many different circumstances, it is always best to have samples of your supply tested periodically by a certified state or private lab.

Preparing Samples

Always prepare your samples from six to 12 representative areas in the poultry house or from at least six different locations in the stockpile. (Samples collected from the stockpile should be taken from a depth of about 18 inches; careful handling will ensure that no soil is intermixed in the sample.) Samples should be taken as close as possible to the time of application; however, allow sufficient time to receive test results.

To collect the sample, obtain a quart of waste from six to 12 locations in the house or stock pile and place them in a large, clean bucket. Mix the contents thoroughly; then place about a quart of the mixed sample into a clean plastic bag or bottle. Seal it tightly, but allow room for the sample to expand. Keep the sample cool; if it is not mailed to the laboratory on the same day as it was withdrawn from the source, then the entire sample should be refrigerated. The accuracy of the lab test depends on the quality of the samples collected. Contact the lab that will be analyzing your sample for information on collection, handling, and shipping.

For Best Results

Both dry and wet samples should be routinely tested on an "as is" basis for total nitrogen, ammonia-nitrogen, phosphorus, and potassium. The key to successful land applications is to apply the right amount of nutrients at the right time, using the right method so that the waste's nutrient content is closely correlated with the nutrient needs of the plants and soil. Be aware that some nutrients will accumulate in the soil and reach high levels; apply the product immediately before planting, during a high growth season, and not in bad weather (when the nutrients may be washed away). Incorporate waste into the soil, if possible. For best results, use biennial soil tests in connection with your manure sample and basic calculations.

Land Application Rates and Methods

Whether the poultry manure or litter waste is taken to nearby farms or spread on your own land, the amount applied, the timing of the applications, and the methods used will affect the outcome. Understanding how the soil and manure or litter interact and calibrating the spreader will help growers apply the right amount at the right time in just the right way.

Manure spread on the surface and not worked into the soil will lose most of its volatile nitrogen compounds, which will be released as ammonia gas to the atmosphere. This release may or may not represent a pollution potential, but such lost nutrients are not available for plant growth.

Poultry waste spread on frozen or snow-covered soil has a high potential for runoff to

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Table 1.—Average Nutrient Composition of Poultry Litter, measured in lbs/ton on an as is basis.

	N	NH_4^+–N	P_2O_5	K_2O	Ca	Mg	S	Na	Fe	Mn	B	Mo	Zn	Cu
Broilers														
Stockpiled litter	36	8	80	34	54	8.0	12.0	6.2	1.5	0.59	0.041	.00069	0.55	0.27
Layers														
Undercage	28	14	31	20	43	6.1	7.1	4.5	0.52	0.27	0.050	.00390	0.32	0.036
Highrise stored	38	18	56	30	86	6.8	8.8	5.0	1.8	0.52	0.046	.00038	0.37	0.043
Turkey Litter														
Stockpiled	36	8	72	33	42	6.8	9.5	6.4	1.5	0.62	0.047	.00095	0.56	0.34
Duck Litter														
Stockpiled	24	5	42	22	27	4.4	5.6	8.8	1.2	0.47	0.030	.00030	0.47	0.50
Liquid Layer														
Liquid slurry	62	42	59	37	35	6.8	8.2	5.3	2.9	0.42	0.040	.018	0.43	0.080
Lagoon sludge	26	8	92	13	71	7.2	12.0	4.2	2.2	2.3	0.082	.014	0.80	0.14
Lagoon liquid	179	154	46	25	266	7.4	52.0	51.0	2.0	0.24	0.37	.020	0.70	0.19

Source: Adapted from Soil Facts: Poultry Manure as a Fertilizer Source (Zublena, Barker, and Carter, 1993).

Key: N = nitrogen
NH_4^+–N = ammonium
P_2O_5 = phosphorus
K_2O = potassium
Ca = calcium
Mg = magnesium
S = sulfur
Na = sodium
Fe = iron
Mn = manganese
B = boron
Mo = molybdenum
Zn = zinc
Cu = copper

surface water. It should not be surface applied to soils near wells, springs, or sinkholes or on slopes adjacent to streams, rivers, or lakes. In fact, some states prohibit this activity. Conservation practices can reduce runoff, nutrient loss, and pollution.

Water pollution potential can be decreased, and the amount of waste nutrients available to plants can be increased, by working poultry waste into the soil either by tillage or by subsurface injection. Subsurface injection of waste only minimally disturbs the soil surface and would be appropriate for reduced till and no-till cropping systems.

Manure or litter must have time to break down before the nutrients in it become available to the crop. Fall applications allow this breakdown to occur, but some of the nitrogen in the manure may be lost through leaching and runoff. Spring applications prevent this nitrogen loss but do not allow enough time for the breakdown of the manure. Incorporation of poultry waste beneath the soil surface in the fall is a way to conserve the nutrients and protect water quality.

Spring and summer applications are recommended based on plant uptake, though it is always important to check for good weather before applications are planned. If litter is applied in bad weather, nutrients may be lost in stormwater runoff. Nutrient-enriched runoff from agriculture could be a leading cause of nonpoint source pollution.

How the poultry waste is applied also affects how quickly the nutrients are incorporated. Generally, incorporation within 12 hours is ideal. The waste can be broadcast over the whole field, followed by incorporation tillage. This method has the advantage of good distribution; because it is visible, the grower can determine the uniformity of the broadcasting. There will, of course, be some odor on the day of the application. Farmers may also want to investigate incorporation, topdress, sidedress, and band application methods.

Spreader Calibrations

Calibration of the spreader machine is also necessary to monitor and control the amount and uniformity of the application. Calibration specifies the combination of settings and travel speed needed to apply nutrients at a desired rate. By knowing a spreader's application rate, and using a few basic calculations found in various fact sheets, a producer can correctly apply the nutrients to meet the needs of the plants. Generally, there are two types of nutrient spreaders — solid or semisolid and liquid. Broiler growers handle solid or semisolid nutrients; many egg producers have liquid waste systems.

Solid or semisolid waste is usually handled in box-type or open-tank spreaders, and the application rate is expressed in tons per acre. Nutrient concentrations in pounds per ton can be estimated, or calculated from the lab analysis. The nutrient application rate in pounds per acre must be determined, based on the tons per acre of waste application.

Liquid or slurry waste is usually handled by tank wagons or irrigation systems, and the application rate is expressed in gallons per acre. Nutrient concentrations in pounds per gallon (or pounds per 1,000 gallons) can be estimated or obtained from lab analysis and used with the application rate in gallons per acre to obtain pounds per acre nutrient applied.

The volumetric capacity of spreaders is generally provided by the manufacturer. Caution should be exercised in using manufacturer's data for spreader volume. A more accurate and preferred approach is to calibrate your own equipment.

Assistance is available from the USDA Natural Resources Conservation Service or Cooperative State Research, Extension, and Education Service offices to calibrate your spreader. Worksheets are available to determine spreader capacity and application rate. Unless the waste has been analyzed for nutrient content and unless the crop soil nutrient needs are known, spreader calibration may have little effect on the application's success.

Once the desired application rate is obtained, record the pertinent information so that you do not have to recalibrate the spreader each time it is used. Spread poultry wastes in a uniform manner. If lush, green growth and not-so-lush growth of plants are observed, adjustments will need to be made during the next application. Calibration of the nutrient spreader is an important practice that is economically and environmentally useful.

A nutrient management plan should be periodically updated to ensure its effectiveness. Often nutrient management can save a producer money by reducing the amount of fertilizer purchased. This reduction in cost is a result of accounting for nutrients already in the soil and manure. For more information, or for nutrient management planning assistance, contact your local USDA Natural Resources Conservation Service or Cooperative Extension Service office or a nutrient management consultant in your area.

References

Barker, J.C. 1990. Livestock Waste Sampling, Analysis, and Calculation of Land Application Rates. Reprint: EBAE 111-84. Agricultural Extension Service, North Carolina State University, Raleigh.

Brodie, H.L., and V.A. Bandel. 1990. Manure Testing. FS-430. Cooperative Extension Service, University of Maryland, College Park.

Fulhage, C.D. 1989. Reduce Environmental Problems with Proper Land Application of Animal Wastes. WQ201. University Extension, University of Missouri, Columbia.

———. 1992. Land Application Considerations for Animal Wastes. WQ202 University Extension, University of Missouri, Columbia.

Goan, H.C., and J. Jared. 1991. Poultry Manure: Proper Handling and Application to Protect Our Water Resources. PB1321. Cooperative Extension Service. North Carolina State University, Raleigh.

Ogburn, C.B., and J.O. Donald. 1990. Calibrating Spreaders for the Application of Animal and Poultry Manure. DPT Circular 11/90-006. Cooperative Extension Service. Auburn University, Auburn, AL.

Woodward, M. No date. Manure Spreader Calibration Work Sheet. Technical Note 4. Cooperative Extension Service, Pennsylvania State University, Lancaster.

Zublena, J.P., J.C. Barker, and T.A. Carter. 1993. Soil Facts: Poultry Manure as a Fertilizer Source. AG-439-5. North Carolina Cooperative Extension Service, Raleigh.

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Economics of Transporting Poultry Manure and Litter

Managing large amounts of poultry litter successfully can involve economic and environmental issues that intertwine and often appear nearly insurmountable. For example, when land suitable for spreading poultry litter as a fertilizer is not available or not under the control of the poultry grower, new markets for land applications and new ways to use the waste must be found. For some years, high quality poultry waste has been marketed both as a fertilizer and as beef cattle feed. Marketing this material involves transportation from the point of production to the point of use.

A Concentrated Industry

The locations of most poultry growers are concentrated within a 25 to 50 mile radius of a hatchery, feed mill, or live-bird processing plant. When the production radius increases over 25 miles, the cost of broiler production increases one cent per pound. This increase, resulting from a combination of labor and transportation, can cost a broiler production unit an additional $2 million annually.

The cost of protecting and preserving water quality must also be applied. Is it better to increase the area of production so that all waste products can be accommodated? Or better to transport the by-products to other areas?

For example, suppose that a broiler complex, which includes pullets and breeders, handles about one million birds a week. These birds will produce about 65,000 tons of litter annually. At the rate of 4 tons per acre, the producer will need 16,250 acres to use the litter for land applications. If more than the one company is operating in the area, even more waste will be produced and more land will be needed.

One alternative to land applications in the area of production is to generate markets or disposal areas at a point some distance from the point of production. Growers will need to find buyers for their poultry waste, and develop a transportation system or delivery network. In some instances, custom cleanout operators will broker and transport the litter for a percent of the profit.

Estimating the Break-even Point

Because of the bulkiness of the solid or semi-solid product, transportation will be the litter buyer's highest cost. An average farm truck can carry 9 to 12 tons. A 30-foot, open trailer used for transporting grains can carry 18 to 24 tons. As load size increases, the cost per ton should decrease.

Figure the cost on a round-trip basis, but if you can schedule back-hauls in the empty truck, you can push the cost even lower. Early estimates predict the cost of transporting litter to be about $1 per mile on a round-trip basis for a 20-ton load. Back-hauls are certainly feasible, with proper attention given to handling, maintenance, and truck cleaning to prevent the spread of pathogenic bacteria and viruses. At least one integrator (Tyson Foods) has approved the use of the same trucks for delivering clean bedding and back-hauling litter.

If the grower is paid a per ton price ranging from $5 to $10, and the litter has a value of $22 to $28 as a fertilizer or $40 to $80 as a feed ingredient; the buyer can afford to transport the litter 100 miles for land applications or up to 300 miles for use as a feed. These distances can be increased if sufficient litter applications are made in the buyers' watersheds to convince farmers that spreading litter on their farms really does improve soil quality and increase crop yields.

The key to this outcome depends on the poultry growers designing and operating animal waste management systems that increase the quality and uniformity of the litter. When both sides are thus engaged, the price of the litter will reflect a fair exchange between what the growers and transporters are paid and the value of the product to the buyers.

Other Practical Considerations

A method is needed for loading raw litter into trucks that have 11-foot sides. Front-end loaders or an elevator that can be loaded with a smaller tractor or skid loader will work. The storage facility must have a smooth hard pad to accommodate the loading process, and the litter must be free of foreign materials such as soil, rocks, broken glass, or other debris. It should also be covered during storage and transportation to prevent losses, protect it from stormwater runoff, and prevent any negative perception of the poultry industry by the public.

Roads and turn-around areas at both ends of the trip must be large enough to accommodate the trucks and the loading and unloading process, and storage facilities must exist at the delivery depot if land applications or other use will be delayed.

The quality of the waste must be protected, and its transport must be biologically secure. Poultry waste should be transported only from well-managed and disease-free farms. All trucks should be properly cleaned and disinfected, and any leakage from the trucks should be drained and diverted from runoff and groundwater. Before being transported off-farm, the product should be deep stacked so that the heat in the stack can kill any harmful microorganisms. The heat level must be monitored to avoid reducing its nitrogen content or creating a fire hazard. Growers may also develop composting or pelletizing treatments to reduce the litter's bulk and odor.

Developing a Transportation Network

The knowledge that litter can be safely and economically transported is not likely to increase its use immediately. In fact, regulations often discourage or prohibit spreading the litter anywhere but on the growers' own crops; and many farmers who have croplands available are convinced that other problems associated with litter, such as handling problems, high transportation costs, and environmental risk, undercut its usefulness. In addition, other waste generators are competing for the same land and can often supply their product at lower cost.

Changing conventional attitudes and helping busy, often undercapitalized farmers develop environmental and market savvy is a long-term objective that requires cooperation among all players: farmers, their research and industry partners, government decisionmakers, environmentalists, and the public.

An example of such cooperation is Winrock International Institute's three-year effort to create a market for poultry litter in Arkansas (see box). Winrock's effort was supported by the USDA Sustainable Agriculture Research and Education program, had many government and private partners, and no doubt, stands among other similarly innovative projects in other regions and countries. It is unique, however, in its determination to use the emerging market for poultry litter to "link and resolve two environmental issues": poor soil quality in some agricultural watersheds and an oversupply of poultry wastes in others.

The Winrock initiative led to progress in rural productivity, sustainability, and equity. It also involved major obstacles:

- farmers are not marketers by training or inclination, and most people living on the margin are risk adverse;
- information and training are difficult to disseminate;
- management practices must be implemented to increase the nitrogen content of litter and its overall quality;
- certification and training are needed for clean-out contractors; and
- emerging markets for litter, like other new product marketing, may need to be subsidized.

More important, perhaps, than any other consideration: the cost of transporting litter long distances and the transportation infrastructure generally must be carefully managed to ensure that the litter being moved is actually moving away from production areas with the most critical environmental stresses.

Ground-testing the Possibilities

Currently, a broker in central Arkansas is shipping about four 24-ton trucks of litter per day to row-crop farmers in the Arkansas delta, Mississippi, and Missouri. The cost to the buyer is $28.50 per ton for litter delivered a distance of several hundred miles.

Most of the transported litter is currently used as a soil builder and yield booster, though high quality, odor-free compost is also being marketed for use on golf courses, and in other specialty markets. These long-haul brokerage services began as enterprising local clean-out businesses. While subsidies are still needed to strengthen the market, the development and acceptance of high quality litter as cattle feed (a higher priced product) could ensure the truckers' long-term future.

At this stage, truckers depend on the research and information campaigns sponsored by federal and local agencies, agricultural foundations, and independent researchers, but the emerging market is also a catalyst for new research and farming opportunities. Indeed, the relationship between animal waste management technologies and a thriving litter transportation market is symbiotic. Both are needed to

- provide additional income to poultry growers,
- depend on incentives rather than regulations to encourage proper waste management practices,
- create a steady demand for litter in less developed watersheds, and
- create new job opportunities as well as cleaner water supplies in rural areas.

When one is convinced that litter is not a waste, but an economic asset, the logical next steps are to demonstrate its value and put it on the market.

Poultry Litter Goes to Market — Winrock's New Approach to Environmental and Rural Development

Rice farmers in western Arkansas often level their fields. The practice makes the fields easier to irrigate and drain and more accessible during bad weather. The grading, however, which is quite labor intensive, also leads to poor yields because it removes so much topsoil. The topsoil can be stockpiled during the grading and respread over the cut red clay; still, it can take some time before the fields return to high yields.

So when university researchers and some farmers began getting high yields using litter on graded soils, word of their success quickly spread to other farms. Soon cotton and soybean farmers were also using poultry litter on fields.

The loss of topsoil on leveled rice fields and other cropping practices are a potential threat to water and soil quality; so is the increasing volume of poultry litter in some regions. Using a well-planned waste management system to ensure that the litter is of high quality, then hauling it out of the threatened regions for application on croplands in other areas will solve both problems. The usefulness of the litter to crop farmers will raise growers' income even as the litter-improved soils lead to higher incomes for the farmers.

Winrock International disseminated the research findings, surveyed farmers and cleanout contractors to identify barriers to moving the litter, then linked the buyers and sellers, researchers and government resources, to begin the long process of creating a multistate market for poultry litter.

In this scenario, market forces replace regulations as a solution for environmental problems. As demand for the litter grows, so will production practices that enhance its quality and lead to new uses. The raw material can be processed for sale as potting soil, topsoil, fertilizer, plant food, and cattle feed ingredient. Moreover, as these products prove successful, other opportunities and products will be developed to increase litter's marketability and value.

The Farm Bureau has continued the project by managing the Poultry Litter Hotline. Call 1-800-467-3898 to buy or sell litter in Arkansas.

References

Donald, J.O., and J.P. Blake. 1990. Economics of Transporting Poultry Litter as a Fertilizer. DTP Circular 10/90-007. Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

J. Harsch. 1995. Poultry Litter Marketing and Utilization Project: A Case Study 1992-1995. Winrock International, Morrillton, AR.

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FEEDING LITTER TO BEEF CATTLE

Cattle, so far as growth and performance can indicate, enjoy a basic diet of corn and soybean meal (for protein) and hay (for long, crude fiber). Broiler and turkey litter and caged layer waste (the latter has no litter content and is often called dried poultry waste [DPW]) can be mixed with the corn/soybean meal and fed to cattle and other ruminants (e.g., sheep and goats). This cost-effective mixture has been a common practice in the beef cattle industry for many years with no adverse effects on the animals' growth or the quality of meat and other food products processed from them for human consumption.

Indeed, as litter is a source of protein, energy, and minerals, its use as a feed ingredient helps conserve nutrients and offset other production costs. Nutrients in the litter (especially, nitrogen, phosphorus, and potassium) and various minerals are recycled to the land when excreted in the ruminants' manure. Therefore, even if the litter must be transported long distances, feeding it to ruminants can be an economical and environmentally sound waste management technique.

Although no problem arises as a result of feeding litter to cattle, the public perception of litter as a cattle feed is often based on misinformation. We readily accept and even prefer vegetables that are organically grown — mushrooms, for example, go directly from the manure bed to the grocery store — but we have a hard time accepting litter as a food ingredient. In reality, beef cattle and other ruminants have a unique digestive system — a four-chambered stomach — that is well able to process wastes and other by-products. A cow's food is broken down and processed much more completely than a plant assimilates food into its tissues.

Regulations on Feeding Litter

In 1967, the Food and Drug Administration (FDA) discouraged the use of litter as a cattle feed. But in 1980, FDA issued a statement leaving it to the states to oversee this practice. At least 22 states have current regulations. No state regulates the private use or exchange of litter for this purpose; many states, however, regulate this commodity on the commercial market.

Many states require that processed broiler litter offered for sale carry warning labels about the presence of any drugs that may be present in the litter. To minimize the potential for drug residues in the cattle, all litter feeding should be discontinued at least 15 days before the animals are marketed for slaughter. This responsibility for selling only wholesome animals falls on the producers, regardless of regulations.

Generally, carefully applied safety precautions — pretreatment (e.g., deep stack) to ensure pathogen control, a 15 day withdrawal period before slaughter, not feeding litter to lactating dairy cows, and not feeding litter with high copper concentrations to copper-sensitive sheep — are sufficient to address health concerns. Litter has in fact been used as a feed ingredient for 35 years without any reported adverse effects on human or animal health.

Nutritional Value of Litter

The kind and amount of bedding material used in a broiler house and the number of batches housed on the litter affect the nutritional value of the litter, which should always be tested before being used as a food product for ruminants. The average nutrient contents are as follows:

- **Moisture.** The moisture content of the manure has little nutritional value; but litter that is too dry may be unpalatable, and litter that is too wet may be difficult to handle as a food ingredient. A moisture content in the range of 12 to 25 percent is acceptable.

▼ **Total Digestible Nutrients.** The sum of crude protein and crude fiber values is used to calculate the total digestible nutrients (TDN) in litter. If the litter has a calculated value of 50 percent TDN, it is comparable to hay as an energy source.

▼ **Crude Protein.** The average amount of crude protein in broiler litter is about 24.9 percent. But about 40 percent of that amount is probably nonprotein nitrogen or uric acid. Young cattle cannot use this nonprotein nitrogen as easily as mature cattle can, so broiler litter should only be fed to cattle weighing over 450 pounds.

▼ **Bound Nitrogen.** Insoluble or bound nitrogen occurs in litter that has been overheated. Bound nitrogen is less easily digested than other nitrogen. Average litter samples have 15 percent bound nitrogen; overheated litter may have as much as 50 percent bound nitrogen.

▼ **Crude Fiber.** The fiber source in litter comes mainly from the bedding materials. Ruminants, however, need long roughage, such as hay. At least 5 percent of the litter ration should be in the form of hay or other long roughage.

▼ **Minerals.** Excessive minerals in litter are not usually a problem, though excessive calcium can cause milk fever in beef cows at calving. Withdrawing the litter from the cows' food for 30 days overcomes this difficulty. Microminerals, such as copper, iron, and magnesium, are also present in large amounts. Copper should not be fed at more than 150 parts per million. It builds up in the liver but is usually not harmful.

▼ **Ash.** Ash content is an indication of litter quality and should not exceed 28 percent. For dirt floor houses, about 12 percent of the ash is made up of calcium, phosphorus, potassium, and trace minerals; the rest is soil. Management techniques that reduce the soil content in the litter should be practiced.

Survey of Broiler Litter Composition

In sum, all litter to be used as a beef ration should be analyzed — tested for nutrient content. Litter used for feed should have at least 18 percent crude protein and less than 28 percent ash. Litter that has too much ash is not suitable as a food ingredient. Not more than 25 percent of the crude protein should be bound or insoluble. If broilers are reared on dirt floors, the litter may be contaminated with soil during cleanout.

The number of broods reared on the litter prior to cleanout of the broiler house also affects the quality of the litter; the more broods reared (five or more), the higher the litter is in nutrients.

Charred litter, that is, litter that has been exposed to too much heat during storage and has a burnt wood appearance, is only half as digestible as litter stored in stacks that were protected from excessive heat.

Processing and Storing Broiler Litter

All litter, regardless of its source, should be processed to eliminate pathogenic organisms such as salmonella; pesticide residues; medicated poultry rations such as antibiotics, coccidiostats, copper, and arsenic.

Dead birds may not be composted with poultry litter if the litter is to be used as a feed ingredient.

Litter can be processed by fermentation (ensiled with other feed ingredients such as corn or sorghum), directly acidified, or heat treated. The easiest, most economical method of treatment is deep stacking. Deep stacking should be done for 20 days or more at a temperature of 130°F. Most of the antibiotics approved for chickens are also approved for cows, and deep stacking inhibits molds (mycotoxins). If stack temperatures exceed 140°F, the deep stack should be covered with a polyethylene tarp to exclude oxygen and avoid overheating. Covered litter stacks will reach a temperature high enough to destroy pathogens but not so high that nitrogen digestibility is threatened.

Suggested Rations

Table 1 indicates rations that can be fed to dry brood cows, lactating cows, and stockers. These rations are recommended guidelines, not abso-

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Table 1.—Suggested Rations.

RATION NUMBER	1 DRY BROOD COW	2 LACTATING COW	3 STOCKERS
Ingredients	**Pounds**		
Broiler Litter	800	650	500
Cracked Corn	200	350	500
Total Pounds	1,000	1,000	1,000

lutes, since the nutrient levels in litter are variable. Vitamin A should be added to all rations. Supplementing winter and summer grazing for stocker cattle increases the animals' weight gain and the total beef produced. To reduce bloating, feed the animals Botavec or Rumensin.

Summary

Because ruminant animals can digest forages, other fibrous materials, and inorganic nitrogen such as urea, the use of litter and DPW as a low-cost alternative feed source for these animals is gaining worldwide attention and acceptance. The use of broiler litter will become more widespread as the need for economy and responsible waste management becomes more urgent.

As animal production continues to increase and to concentrate geographically, more waste is produced than can be assimilated by land applications. However, when the litter is properly processed and stored, it can be used as a dietary supplement for cattle resulting in a lower winter feed cost for cattle and a cost-effective way to increase the average daily weight gain of cattle during the stocker production phase — the phase that begins after weaning and continues until the cattle are placed in the feedlot. This alternative to land application helps reduce the environmental risks and adds value to the litter. Since management practices on the farm affect the litter's quality, attempts to market the litter as a feed ingredient begin with a focus on management techniques.

References

McCaskey, T.A., A.H. Stephenson, and B.G. Ruffin. 1990. Factors that Influence the Marketability and Use of Broiler litter as an Alternative Feed Ingredient. Pages 197-203 *in* Proceedings of the Sixth International Symposium on Agricultural and Food Processing Wastes. American Society of Agriculture Engineers, Chicago, IL.

Ruffin, B.G., and T.A. McCaskey. 1990. Feeding Broiler Litter to Beef Cattle. Circular ANR-557. Cooperative Extension Service, Auburn University, Auburn, AL.

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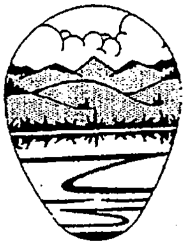

HORTICULTURAL USES OF LITTER

Because it has essentially no unpleasant odors, well-composted broiler litter can be used indoors in a soilless potting medium. In fact, its nutrient content makes litter an ideal fertilizer for both indoor and outdoor gardens. It is also a good organic material for improving soil structure and drainage.

Soil Amendment

Gardeners can add composted litter to soils that otherwise contain too much sand or clay to support a garden. Work the top soil loose to a depth of 1 foot; then, spread 3 or 4 inches of compost on the soil. About 2 inches of compost may suffice at a minimum, but in really poor soils, 6 inches can be applied. Turn the soil over after the application to incorporate the compost.

Flower and Vegetable Transplants

Annual and perennial flowers and vegetable transplants also do well in compost-amended settings. Use a trowel to dig a hole in the new location. Remove the plant from its container and tear a hole in the bottom of the root-ball — otherwise, the roots will continue to grow in a tight circle — before setting it into the ground. Fill the hole with amended soil and water thoroughly. Mulching will help the plants retain water, thereby conserving this resource as well.

Transplanting Trees and Shrubs

If you are transplanting trees or shrubs, use the techniques listed above, but make sure that the hole you dig for the plant is at least twice the size of its present container. Work about 3 to 6 inches of composted litter into the soil in the hole and place the tree or shrub therein. Keep as much soil as possible around the root-ball when you take it out of the container. Do, by all means, remove the container, especially if it is plastic, so that the new growth will have plenty of room. The soil line on your plant should be level with your garden. Fill in the hole with the amended soil, and water the plant thoroughly to remove any air pockets that may have been in the backfill.

Potting Mix for Indoor Plants

To make your own potting medium, use equal parts of composted litter and composted pine bark — all living things need nitrogen and carbon. The bark may be screened to remove large pieces (one-half inch or larger) before mixing. Fill the new pot with 1 or 2 inches of the planting medium, spread out the roots of your plant, and set it in the pot. Remove any buds or flowers before replanting to ensure that the plant has time to get properly established. Transplant from one pot size to the next one only; skip one size if you have to, but don't go from a 1-inch pot to a 4-inch pot and expect to succeed. Water the plants in the fall and winter; fertilize them in the growing seasons — spring and summer.

Lawns

Composted broiler litter is a superior product to use to establish new lawn areas. Spread about 2 inches of composted litter on the area to be seeded. Then turn the soil over to a depth of 6 inches to incorporate the material. Place turf on the prepared soil and water it as usual. The addition of compost to the soil helps hold moisture and improves drainage.

Fertilizer

The nutritional analysis of composted litter will vary, depending on conditions of waste production and handling, among other variables. However, most composted litter will have an analysis similar to 2-2-2 commercial fertilizer. That is, it should have no less than 2 percent nitrogen (N), 2 percent phosphorus acid (P_2O_5), and no less than 2 percent potassium as potash (K_2O). Two quarts of broiler litter compost can be applied monthly to your vegetable and flowering plants. It should be worked into the soil lightly — at the drip line or where the water falls naturally from the leaves.

References

Behe, B.K. 1990. Horticultural Uses of Composted Broiler Litter. Poultry By-product Management, Horticulture. DTP Circular 11/90-012. Cooperative Extension Service, Auburn University, Auburn, AL.

Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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Controlling The Effects of Ammonia and Phosphorus

The effects of ammonia volatilization from litter can be significant at levels above 25 parts per million. It may adversely affect the birds' growth rate, feed efficiency, and egg production; damages the respiratory track; and increases the birds' susceptibility to a variety of avian diseases, including Newcastle disease, airsaculitis, *Mycoplasma gallisepticum*, and keratoconjunctivitis.

Ammonia volatilization from litter also contributes to acid rain. In Europe livestock wastes are considered the dominant source of ammonia pollution in acid rain, and emissions increased as much as 50 percent in the three decades leading to 1980.

Methods to reduce ammonia volatilization from litter usually require good housekeeping, proper ventilation, and perhaps chemical additives. Remediation can be costly but prevention is cost-effective and beneficial to farm workers, poultry, and the environment.

Ammonia emissions from litter during broiler production adversely affect bird health, increase ventilation costs, and cause significant ammonia emissions to the air. Improving nitrogen efficiency by feeding the flock amino acid diets can reduce the content of nitrogen in excrement and help control ammonia emissions.

Ventilating the poultry house before you have a problem; for example, when the house is new, the birds are young, and after cleanouts, is essential. Unless the house is properly ventilated at these times, ammonia problems may be just around the corner. Ventilating to prevent the problem will save growers increased heating and ventilation costs later in the growout.

Another tip: don't let your nose be your sensor. After several years in the poultry business, you may tolerate a higher level of ammonia in the air than is good for you or your operation. First time growers may be sensitive to ammonia at 10 parts per million; seasoned growers may be unaware of levels as high as 60 ppm. Operating costs, especially for fuel, will be lower at these levels, but so will the birds' performance.

Controlling house humidity will help you manage the ammonia and prevent litter from caking; it will also help control carbon dioxide, dust, and oxygen levels. Humidity in the house should be kept (ideally) at 50 to 70 percent.

Diluting the moist air inside the house with fresh outside air is the key to humidity control, so watch the weather. Warm, humid days will obviously increase the need for ventilation. Because it can be so difficult to gauge how much fresh air is needed, Georgia's Cooperative Extension Service has developed a list of timer settings and number of fans needed to maintain the average humidity in a 40 by 500-foot house during the six or eight weeks of growout (see Tables 1 and 2). You will want to check the weather conditions and perhaps consult with the Cooperative Extension office nearest your facility before adopting these tables.

Two other tips: First, if you are using the tables, consider the timer settings as minimum suggestions when the birds are young. The settings may be adjusted down slightly during extremely cold weather when the birds are older. To help you determine how much leeway you have, an inexpensive relative humidity and temperature gauge will be as useful as more expensive ammonia meters. The difference in

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Table 1.—Small Birds (30,000).

BIRD AGE (weeks)	SECONDS ON (5-minute timer)	NUMBER OF 36" FANS
1	30	2
2	60	2
3	90	3
4	120	3
5	150	4
6	180	4

Table 2.—Big Birds (24,000).

BIRD AGE (weeks)	SECONDS ON (5-minute timer)	NUMBER OF 36" FANS
1	30	2
2	60	2
3	60	3
4	90	3
5	120	3
6	120	4
7	150	4
8	180	4

price will be significant: $30 as opposed to $1,500, and the ammonia meter may not last more than a year or two in a poultry house.

Second, be sure to check the drinker line height and pressure. Adding additional water to the house through improper drinker operation will skew the tables and cost you money. It takes about 12,000 cubic feet of air to get rid of a gallon of water. So wasting five gallons of water, will increase your ventilation rates by 1,000 cubic feet per minute. If the fresh air also has to be heated, you will probably use an additional half-gallon of propane per hour.

Phosphorus runoff from fields and ammonia entering the air are two problems associated with poultry litter. The amount of water soluble phosphorus in litter varies depending on its source and management. For example,

- fresh broiler litter contains 1.23 grams of water soluble phosphorus per kilogram of litter,
- stacked litter, 2.29 grams;
- dead bird compost, 2.15 grams;
- caged layer manure, 2.68 grams; and
- turkey litter, 3.02 grams.

The addition of alum (aluminum sulfate) has been reported to reduce ammonia levels in the house and to decrease phosphorus runoff when the litter is spread on pasture. The reduction in phosphorus runoff have been as high as 87 percent.

Other litter additives are available in addition to alum that, by acidifying the litter, are reported to decrease the levels of ammonia in the air of poultry houses. Alum is the only one that is reported to also reduce phosphorus runoff when the treated litter is applied to the land. The acidification of the litter is also reported to reduce the levels of bacteria in the litter thus having a potential food safety benefit.

Concerns have been expressed over the safety of workers applying alum to the litter. As a result, the manufacturer now supplies it in a low-dust granular form and suggests the use of goggles and particle dust masks by the individual applying the alum to the litter.

References

Czarick, M. and M.P. Lacy. 1997. Ammonia Levels Need to Be Monitored for Ventilation Effects. Poultry Times, June 16, pp. 22-23.

Moore, P.A. Jr. 1995. Phosphorus Precipitation in Poultry Litter with Al, Ca and Fe Amendments. Completed Research, Project 102. Southeasten Poultry and Egg Association, Tucker, Georgia.

Moore, P.A., Jr., P.C. Daniel, D.R. Edwards, and D.M. Miller. 1996. Evaluation of Chemical Amendments to Reduce Ammonia Volatilization from Poultry Litter. Poultry Science 75:315-320.

Moore, P.A., Jr., W.E. Huff, T.C. Sauer, T.C. Daniel, and D.R. Edwards. 1996. A Simple Method for Measuring Ammonia Volatilization from Poultry Litter. Presentation at the 85th Annual Meeting of the Poultry Science Association, Inc., July 8-12, in Louisville, KY.

Paul, J.W., P.K. Barton, D. Kermode, and T.A. Scott. 1997. Measuring Ammonia Emissions from Poultry Broilers Fed Balanced Amino Acid Diets. Agriculture and Agri-Food Canada, Pacific Agricultural Research Center, Agassiz, BC, Canada.

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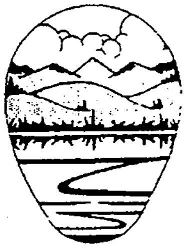

An Overview of Poultry Mortality Management

Responsibility for the safe and nonwasteful management of dead birds — a challenge for the poultry industry — is a practical problem that growers face on a near daily basis. It begins with choosing the best method for the proper disposal of the carcasses. Because dead birds constitute a large portion of the total wastes generated in poultry production, their disposal must be biologically secure, environmentally safe and cost effective.

Most normal mortalities occur during the first and last two weeks of the growing cycle for broilers and from 10 to 13 weeks of age for layers. Normal mortality for broiler production is 3 to 5 percent over the production cycle or about 0.1 percent per day. Thus, for example, in a flock of 100,000 broilers grown 49 days, as many as 5,000 may die. A single grower, assuming that a typical broiler house holds 20,000 birds weighing 2 to 4 pounds, may have as many as 85 pounds of dead birds to dispose of each day near the end of the growing cycle. A roaster operation may have to dispose of as many as 115 pounds per day, and a turkey operation may dispose of 150 to 200 pounds per day.

Mortality rates in other kinds of poultry operations will be similar to or somewhat lower than the rate for broilers. The exact number of daily mortalities will vary depending on the number of birds on hand as well as their size and age. Massive die-offs, catastrophic losses, and spent (unproductive) hens are additional challenges.

Burial in specifically designed pits, incineration, and rendering are the most common methods of disposal, though environmental, economic, and practical concerns have fueled interest in composting as a fourth alternative. Each of these methods is supported by best management practice guidelines. Newer technologies, for example, small-bin composting, fermentation, and refrigeration, are also emerging in field trials as individuals, the industry, and agricultural researchers seek to meet the challenge of mortality management.

Burial Pits

Burial pits are not always practical and may not always be permitted. The earliest burial pits (which were only adequate for very small operations) were simply holes dug in the ground with a small opening at the top. Depending on geologic and weather conditions, such pits will almost certainly affect water quality. Therefore, for many poultry producers, they are no longer an option given the intensity and concentration of today's industry. Where burial pits are still allowed, they generally require a permit and must be properly "constructed," sized, and located. They must also be tightly covered for safety and to prevent odors.

Incineration

Incineration is an acceptable and popular alternative to the use of burial pits. It is also biologically safe (the burning destroys pathogens), and poses no threat to surface or groundwater though care must be taken to insure that smokestacks do not create air quality problems or nuisance odors.

Historically, incineration has been the most costly method of mortality disposal. However, a new generation of improved incinerators may defeat this obstacle, particularly since the newer equipment also complies with air quality standards.

The Composting Alternative

Composting dead birds emerged as an acceptable method of mortality disposal only in the 1980s. Composting, however, is an ancient and natural waste-management technique that continued to be practiced with little change throughout the 18th and 19th centuries. In all that time, composting methods and speed differed little from the decomposition of organic matter that occurs naturally. The current use of composting as a managed method of mortality disposal improves on that technique to fulfill the biological, environmental, and cost criteria that must be met to qualify as an approved method. Pathogens cannot survive the increased temperatures associated with composting, odor and insects can be controlled, and air and water quality are protected. As an additional advantage, composting results in an inoffensive and value added end product that can be stockpiled until needed as a fertilizer or soil amendment. Each carcass is, in fact, 2 to 9 percent nitrogen, 1 to 4 percent total phosphorus, and 1 to 7 percent total potassium.

Rendering

Rendering may be the safest way to dispose of mortalities, at least from an environmental point of view. It, like composting, adds value to the end product — in this case, the carcasses are processed into biologically safe, protein and nutrient-enriched feed-mill products, such as feather meal and other dietary supplements for poultry and other animals.

Major drawbacks to rendering are the difficulty of transporting the carcasses to the renderer's plant while they are still fresh, and concern that disease or disease-causing organisms might be picked up in the vehicle or at the rendering plant and unintentionally returned to the farm.

On-farm fermentation offers growers a way to preserve the carcasses until they can be delivered to the renderer. The carcasses are collected, put through a grinder and mixed with a carbohydrate. Bacteria common in the birds' intestines ferment the carbohydrate to lactic acid, which neutralizes pathogens but preserves the nutrients, thus permitting the product to be held a longer time on the farm. Refrigeration or freezing is another method to preserve dead birds prior to their delivery to a rendering plant.

Decision Criteria

Growers must carefully consider the trade-offs — the differences in resource requirements and outcomes involved in these mortality management practices — and the effect of local conditions and personal preferences to determine the method of mortality management that best fulfills their need. Table 1 compares the methods by cost and in relation to size, environmental concern, and marketing considerations. Other characteristics may be important to some growers.

In all cases, unsanctioned methods, such as feeding the carcasses to hogs or other domestic animals or abandoning them in sinkholes or creeks or in the wild, should not be attempted. Nor can dead birds be delivered to municipal landfills. Dead bird disposal is a potential health hazard and a regulated activity. Growers must choose the permitted disposal method that best suits their management style and perform it according to strictly maintained standards to ensure sanitary conditions and the least possible environmental consequences.

Growers should check with their state agencies (environmental, agricultural, and animal veterinary medicine) to be certain that their plans comply with all dead animal disposal regulations. The USDA Natural Resources Conservation Service and Cooperative Extension Service offices can be of assistance.

More detailed discussions of burial pits, incineration, rendering, and composting as methods for managing dead birds can be found in subsequent fact sheets in this section of the handbook.

References

Blake, J.P. 1993. Mortality Management. Presentation. Poultry Waste Management and Water Quality Workshop. Southeastern Poultry and Egg Association, Atlanta, GA.

Crews, J.R., J.O. Donald, and J.P. Blake. 1995. An Economic Evaluation of Dead Bird Disposal Systems. Circular ANR-914. Alabama Cooperative Extension Service, Auburn, AL.

Payne, V.W.E., and J.O. Donald. 1991. Poultry Waste Management and Environmental Protection Manual. Circular ANR-580. Alabama Cooperative Extension Service, Auburn, AL.

Table 1.—Characteristics of Dead-Bird Disposal Systems.

	EXISTING TECHNOLOGIES				EMERGING TECHNOLOGIES	
Item	Disposal Pit	Incineration	Large-Bin Compost	Small-Bin Compost	Fermentation	Refrigeration
Initial investment cost	M	L	M	L	H	H
Variable cost	L	H	M	M	M	H
Fixed cost	M	L	M	L	M	H
Value of by-product	N	N	H	H	M	M
Net cost	L	H	M	L	M	H
Cost sensitivity to size	L	L	H	L	H	L
Flock size limitations	L	M	L	H	L	L
Environmental concern	H	M	L	L	N	N
Market constraints	N	L	N	L	H	H

KEY: H=high M=medium L=low N=none

Adapted from Crews, Donald, and Blake, 1995.

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Burial — A Disposal Method for Dead Birds

The burial of dead birds in trenches, open pits, and landfills is rarely an acceptable method of dead bird disposal. In Arkansas and Alabama, no new in-ground burial pits are permitted — and states that do permit them consider this option the least desirable method or the method of last resort for mortality management. Until recently, however, burial was the only practical method some growers had to dispose of their dead birds — despite its potential for water pollution. Its use is now hedged with various guidelines and restrictions, such as construction requirements, loading rates, and setback distances from water resources, residences, and property lines. In all cases, the pits must be fabricated.

Pit Design and Fabrication

A fabricated burial pit is an open-bottomed, reinforced hole in the ground that has one or more openings at the top through which carcasses are dropped. An airtight cover above the openings prevents odors from escaping. The pit provides an environment in which aerobic and anaerobic microorganisms can consume most of the organic material. Only the feathers and bones should be left. Although disposal pits require minimal labor and supervision, they must be maintained in a sanitary, legal, and socially acceptable manner.

Fabricated pits should be made of concrete block, poured concrete, or treated timbers. Some prefabricated pits can be purchased from septic tank dealers and delivered to the farm ready for installation. Under no circumstances, however, should the pit be simply a hole in the ground dug with a backhoe and lined with tin. The decomposition process will produce very little water inside the pit, but the pit should be covered with soil and planted to vegetation to carry water away from the pit and to protect it from access by heavy equipment.

The openings — also called drop chutes — are made of plastic (PVC) pipes, which protrude out of the mound at intervals of five feet. The chutes should have tightly fitted but removable covers. The bottom of the pit is earthen with holes at intervals up the sides.

Location

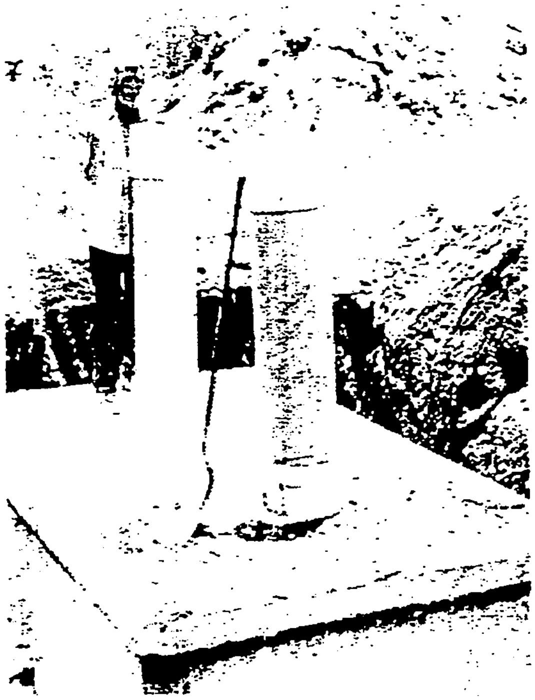
Location guidelines established by state agencies to protect water resources should be carefully observed. Generally, a disposal pit should be located at least 200 to 300 feet from dwellings and the nearest water well, 50 feet from property lines, 25 feet from the poultry house and 100 to 300 feet from any flowing stream or public body of water.

Before constructing a disposal pit, make certain that the soil composition is acceptable. Bedrock (especially limestone) and sandy soils should be avoided. Locate pits in soil where good surface runoff will occur. Sandy soils are not suitable for pit installations.

To prevent groundwater contamination, the pit's lowest point should be at least five feet above the highest known water table and at least five feet above bedrock to keep contamination from traveling along a rock fissure. To prevent water from seeping into the pit, construction on a slope, floodplain, or low-lying area should be avoided and in some states is not permitted.

Pit Size

The pit itself should be at least six feet deep with reinforced walls. Its size will depend on several factors, including the expected mortal-



Properly constructed disposal pits are made of concrete block, poured concrete, or treated timbers.

ity rate of the flock, bird size, and environmental conditions. Use the following table to estimate pit size:

TYPE OF MORTALITY	PIT SIZE IN CUBIC FEET PER 1,000 BIRDS
Broilers	50
Turkeys (to 18 weeks)	100
Layers (commercial)	55

For broiler mortalities, for example, if you have a 5 percent mortality rate in a flock of 20,000 and you raise five flocks per year, your burial pit should contain at least 250 cubic feet of disposal space. That is, it should be about six feet deep, six feet wide, and about seven feet long. Sometimes it can be more convenient to use several smaller pits to prevent overloading. In cooler climates, the pit size should be larger to accommodate a slower rate of decomposition. Keep in mind that some states may have maximum loading rates depending on the area's vulnerability to groundwater pollution.

Durability and Cost

The life of the pit will depend on its location and whether it is properly sized, constructed, and managed. To ensure total decomposition, the pit must be operated efficiently to protect the bacterial population. High acidity, for example, will retard the decomposition of dead birds. Disposal pits are most efficient during warmer months when bacterial action is greatest. Decomposition is slowed by winter temperatures or by accumulation of water in the pit. Grinding the carcasses or splitting open the dead birds (puncturing the abdominal cavity) will expel gases, increase the pit's efficiency, and extend its life.

The cost of constructing disposal pits varies widely depending on the materials used, site conditions, and the size of the pit. Geologic conditions — rocky soil, for example — can make digging expensive. As pit size increases, heavier construction is required for walls and tops; thus, higher costs are incurred. For a well-built pit, a useful life of five years is not uncommon, and some producers have reported that pits can be useful for eight to 10 years. Replacement is required when the pit is full.

Operation

After a pit is constructed, producers should check their facilities twice daily for mortalities and transfer them immediately to the pit. (Current law requires dead animals to be properly disposed of within 24 hours.) Covers on the drop chutes should be kept closed at all times to prevent odor and restrict access by children, animals, and rodents. Certain insects in a disposal pit are beneficial to the decomposition of the carcasses, but insects should not be allowed to develop into a nuisance. With proper handling the disposal pit costs nothing to maintain except for the labor of collecting the carcasses.

Drawbacks

Burial pits may attract flies and scavengers, and they may emit offensive odors. Further, today's farm may have insufficient land space for burial pits, or the capacity of the pits may be limited in winter. If the oxygen supply is insufficient, the decomposition process will be arrested. Slacked lime can be added to the burial pit to break down the tissue of the dead birds. It will also, in effect, sterilize the remains. If the site has poor soils or a high water table, groundwater pollution is a distinct possibility.

Before constructing or installing a prefabricated disposal pit, poultry producers should consult with their state's veterinary specialist, other agricultural offices, and environmental or natural resource agencies. These agencies may regulate the use of burial pits or disallow their use entirely, so seeking expert guidance before production begins often saves time and money. Local USDA Natural Resources Conservation Service or Cooperative Extension Service offices can provide technical assistance to growers who want to use disposal pits as part of their mortality management plans.

References

Arkansas Soil and Water Conservation Commission and the Water Resources Center. No date. Water Quality and Poultry Disposal Pits. Fact Sheet 2. Arkansas Soil and Water Conservation Commission, Little Rock AR.

Donald, J.O., and J.P. Blake. 1990. Use and Construction of Poultry Burial Pits. DTP Circular 10/90-013. Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Wineland, M.J., and T.A. Carter. 1987. Poultry Science and Technology Guide — Proper Disposal of Dead Poultry. PS&T Guide No. 19. North Carolina Agricultural Extension Service, Raleigh.

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Incineration — A Disposal Method for Dead Birds

Incineration, or cremation, is a safe method of carcass disposal and may be the method of choice in areas plagued by poor drainage and rocky soils. The major advantage of incineration is its ability to curtail disease. It is biologically secure, and it does not create water pollution problems. Even its by-product — ashes — is minimal, easy to dispose of, and unlikely to attract rodents or pests.

On the other hand, incinerators can be a costly item to install and operate and are expected to become more expensive as fuel costs rise. Further, while incineration destroys pathogens and poses no risk to water, its effect on air quality must be carefully monitored by poultry growers who choose this method of mortality management.

Incineration is not, then, a casual or inexpensive undertaking. Barrels or other homemade vessels are unsatisfactory burners and have serious consequences for the grower if they result in air pollution or unpleasant odors. Using incineration to manage poultry mortalities must be carefully planned: it must comply with dead animal regulations, meet all air quality standards, and justify investments in commercial equipment and the risk of increasing energy costs.

Notwithstanding these drawbacks, incineration is biologically the safest method of mortality management and simultaneously the method most likely to protect water resources. Producers considering this method of mortality management should consult with their state's agricultural, environmental, and veterinary medical agencies on the best way to incorporate this method. Agricultural incinerators do not generally require a permit, but they are designed to handle Type 4 wastes (e.g., animal remains, carcasses, organs, and solid tissue from farms and animal labs), but not other wastes (e.g., plastics and other organics).

Good Incinerator Design

A variety of commercial incinerators are available, and each one should be installed according to the manufacturer's specifications and local codes — typically outside, but under a roofed structure and away from any combustibles.

Incinerators should be sturdily built and able to accommodate daily mortalities. Indeed they should be sized to handle large loads and high temperatures; however, very large-scale loads, for example, loads running over 100 pounds per hour may require an operating permit. Growers should carefully estimate the capacity needed to manage daily mortalities and include other disposal methods in their resource management plans to cover situations in which heavy, unexpected losses can occur.

A variety of commercial incinerators are available.

An incinerator's material qualities are unlikely to become a problem if the unit is bought from a reputable dealer since stainless, aluminized, or heat-tempered steel is commonly used in their construction. Insulated models and those with heat shields may save energy and minimize the unit's exterior temperature. Those that have automatic controls will be more convenient and perhaps more economical.

Location and Operation

Incinerators should be used daily, so putting them in an area convenient to the poultry house will contribute to better management. Sheltering the incinerator from inclement weather will extend the life of the unit. For best results, it can be placed on a concrete slab.

To avoid nuisance complaints, locate the unit downwind of the poultry house, residences, and neighbors' residences. Finally, always check that the discharge stack is far enough away from trees or wooden structures to avoid fires, since incinerators burn at intensely high temperatures.

Incinerator Costs

Cost is no doubt the chief factor limiting the use of incineration in mortality management. The total investment includes the initial purchase, subsequent maintenance, and the interplay between the rate of burn and the price of fuel. Equipment costs vary depending on the size and type of the incinerator. Afterburner devices that recycle the fumes will help control odors and dust but will likely be priced as accessories. Expendable parts and grates will also need to be replaced periodically — perhaps every two or three years — and the whole system may need replacement (or overhaul) every five to seven years.

The rate of burn will vary depending on the weight, moisture, and fat content of the carcasses and on the loading capacity of the unit (e.g., incinerators may have to be loaded several times to handle a day's mortalities). Assuming an average burn rate of about 65 pounds per hour (based on past experience), and a fuel cost of $0.61 per gallon, a grower will expend $3.50 per day to incinerate 100 pounds of mortalities (1990 estimates). If fuel prices increase, so will the cost of each day's burn.

Growers have for the most part been unwilling to risk the high costs involved in this process, since they have no control over the price of fuel, and because the choice of incineration also means the loss of any nutrient value that the mortalities might have had if composted for land applications or rendered for other uses.

New technology may be the key to changing attitudes about incineration. Influenced by technological advances, current manufacturing specifications are producing a generation of incinerators that last longer, control emissions better, and burn more efficiently than older models in the field. Simply put: the new performance standards make it possible to separate the cost of incineration from the rising price of fuels. Thus, for example, trials on newer models have accomplished the same daily burn for less money than for older incinerators, even though fuel rates used in the computations were higher than those actually charged in 1990.

Incineration is an acceptable and safe method of poultry mortality management. It does not risk the spread of disease or water pollution. If, as now seems likely, technology succeeds in controlling its cost and its air emissions, incineration will become more competitive among the various methods available for managing this aspect of production. Growers considering incineration as a method of poultry mortality management are encouraged to plan this action in connection with their entire resource management system.

References

Brown, W.R. 1993. Composting Poultry Manure. Presentation. Poultry Waste Management and Water Quality Workshop. Southeastern Poultry and Egg Association, Atlanta, GA.

Donald, J.O., and J.P. Blake. 1990. Installation and Use of Incinerators. DPT Circular 11/90-014. Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

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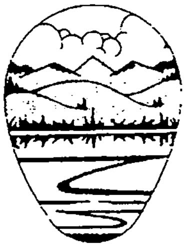

Composting — A Disposal Method for Dead Birds

Composting poultry mortalities or dead birds is a relatively new, practical, and sanitary alternative to burial pits and incinerators. It is an economical, fairly odorless, and biologically sound practice for broiler, turkey, layer, and Cornish hen operations. Management commitment is the key to successful composting.

Composting resolves the disposal problem and yields a valuable product — a reduced odor, spongy, humus-like material that has several marketable uses ranging from soil conditioner to horticultural growing medium. Some states may require that composted birds be applied to the grower's own land; even so, composting has other values:

- Composting is environmentally sound; properly done, it decreases the potential for surface and groundwater contamination.
- Composting destroys disease-causing organisms and fly larvae.
- The materials needed for composting — mortalities, litter, and sometimes straw and water — are readily available.
- Once a composting system has been set up, it will not require much labor; and
- Compared to other options, composting is not a costly method of mortality disposal.

A Natural Process

Composting is a controlled, natural aerobic process in which heat, bacteria, and fungi fueled by carbon, nitrogen, oxygen, and moisture decompose organic waste, changing it into a stable product.

The grower's tasks are to collect the carcasses and place them in alternating layers with the manure and straw (or other carbon source); and to monitor the process to ensure that enough heat is being generated to complete the process of decomposition. The grower will also turn the composting mixture, usually by moving it from one bin into another. Turning the compost ensures that the entire mass is sufficiently aerated.

Composter Design and Operation

Composting poultry mortalities can be done in or outside the poultry house, but it should always be done in an environmentally safe and healthy manner, under a roof, and protected from rain, stormwater, or surface water flow. Most poultry mortalities will be composted in a facility housing a two-stage large bin composter. A typical two-stage large bin composter is designed as follows:

- The size of the primary bins is determined by the following equation:

V = flock size x (rate of mortality / total number of days) x average market weight x 2.5 cubic feet

  The secondary bins should be equal to, or larger, than the primary bins, since experience teaches that one cubic foot of primary bin and one cubic foot of secondary bin is needed per pound of daily mortality.

- The height of bins should not exceed 5 feet. Heights greater than 5 feet increase compaction and the potential for overheating.
- The width of the bins is usually selected to accommodate the loading equipment. A width of 8 to 10 feet is normal, but the bins could be wider.

- The depth of large bins is not restricted, assuming that the operator has appropriate mechanized equipment to manipulate the compost from front to back. Deeper bins are more difficult to enter and exit and take more time to work. Secondary bins can be larger, but they must have the same capacity as the primary bins (see Fig. 1).

- Extra primary bins will provide useful storage for litter and straw. If high mortalities occur, these bins could be used for composting.

- The ceiling height of the composter should be high enough to accommodate a front-end loader extended upward.

The decision to use a composting system for poultry mortality management means that the grower is committed to managing the composter facility properly and seeking help as needed. Once the composter bins have been adequately designed, the building itself should be considered. A few general principles apply to the composting facility.

- **Location and Access.** The composting facility should not be located near any residence. Offensive odors are possible during the composting process; and the handling of dead birds, manure, and litter on a daily basis may not be aesthetically pleasing. The site should be well drained and accessible; farm equipment is usually needed to carry dead birds and compost ingredients to the composter and to remove the finished compost.

- **Foundations.** An impervious, weight-bearing foundation or floor, preferably of concrete, should be provided under primary and secondary composting bins. Experience has shown that after frequent loading and unloading activities, dirt or gravel tends to become rutted and potholed. A good foundation ensures all-weather operation, helps secure against rodent and animal activity, and minimizes the potential for pollution of surrounding areas.

- **Building Materials and Design.** Pressure-treated lumber or other rot-resistant materials are necessary. A roofed composter ensures year-round, all-weather operation, helps control stormwater runoff, and preserves composting ingredients. Adequate roof height is also needed for clearance when using a front-end loader.

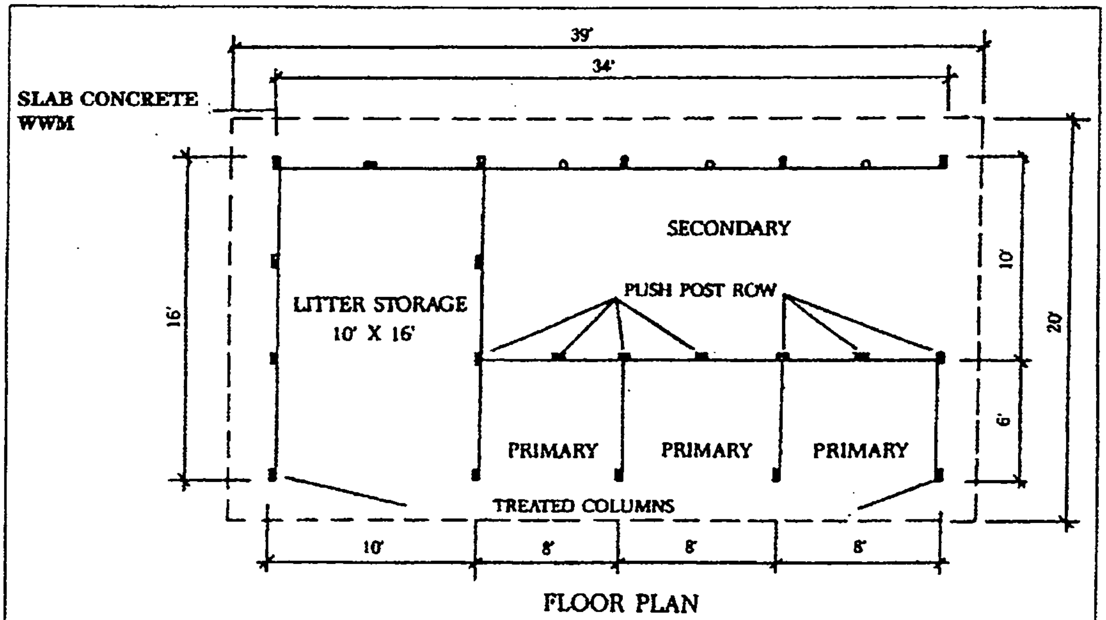

Figure 1.—Typical two-stage composter floor plan (not to scale).

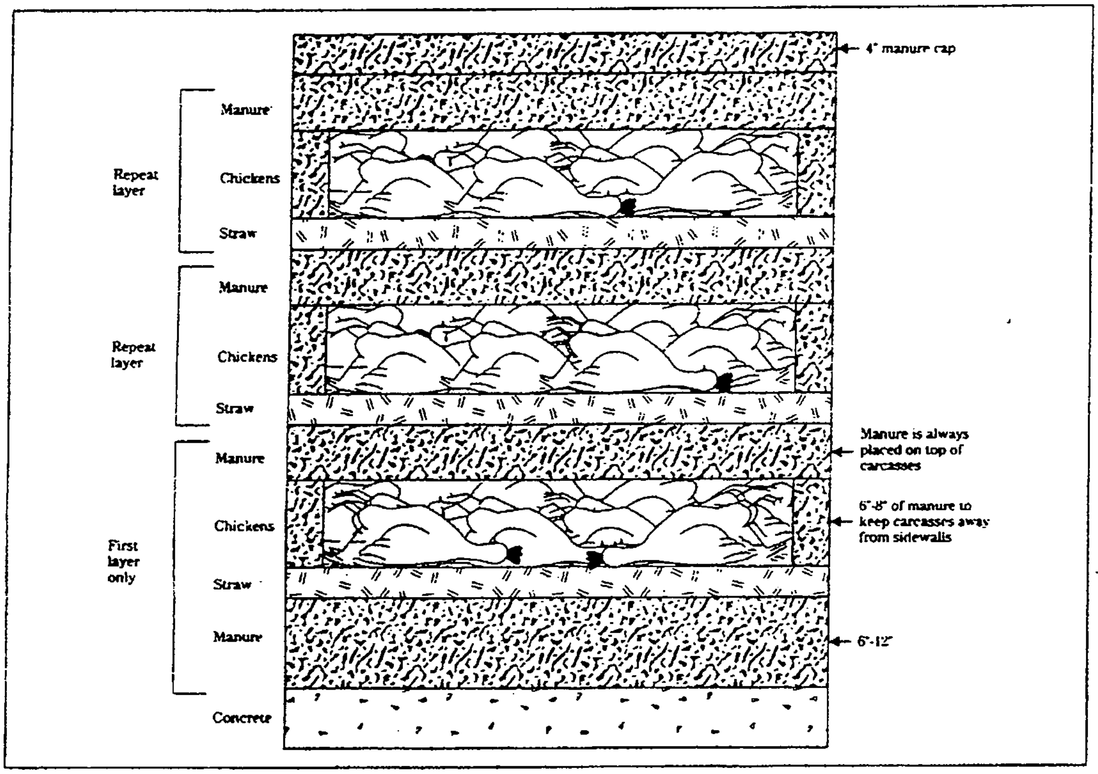

Figure 2.—Recommended layering for dead bird composting.

The amount of rain that is blown into the composter can be minimized by the addition of partial sidewalls or curtains and guttering along the roof.

Composting Recipe and Method

For composting poultry mortalities in a two-stage composter, a prescribed mixture of ingredients is used called a "recipe." The recipe calls for dead birds, litter, straw or other carbon source, and water (Table 1). Recipes for a single-stage composter differ slightly.

Proper layering of the recipe will ensure appropriate heat (from microbiological activity) for composting the mortalities in about 14 days. To begin, place 6 to 12 inches of litter or manure, followed by a 6-inch layer of loose straw to provide aeration, followed by a layer of dead birds. Depending on the moisture content of the manure or cake, water may or may not be added. Repeat this layering process until the pile or bin is full (see Fig. 2).

Table 1.—Typical recipe for composting dead birds with litter, straw, and water as ingredients.

INGREDIENTS	PARTS BY VOLUME
Dead Birds	1.0
Litter	1.5
Straw	0.5 – 0.75
Water	0.0 – 0.5

Water as an ingredient may not be necessary. Too much water can result in anaerobic conditions. An alternate recipe uses 1 part birds with 2 to 3 parts of litter cake (i.e., litter having a high moisture content).

Leave 6 to 8 inches of space between the edges of the dead bird layer and the wooden wall of the composter. This space allows air movement around the pile and keeps carcasses nearer to the center of the pile, where the heat is highest. Do not stack dead birds on top of each other. They may be adjacent to one another, even touching, but they must be arranged in a single layer. Spread litter or manure and straw as evenly as possible.

Use the same layering sequence (dead birds, litter, and straw) after loading mortalities that only partially complete a layer. If dead birds are carelessly loaded — stacked one on another or placed against the sidewalls of the structure — they will putrefy. Once the compost pile is complete, or full, "cap it off" with a 6-inch layer of dry litter, manure, straw, or similar material to reduce the potential for attracting flies and to provide a more pleasing appearance. This same recipe can be used for composting caged layers, broilers, turkeys, breeders, or other types of poultry.

Mixing, aerating, and moving the composting mass with a front-end loader or shovel will uniformly distribute the ingredients, add oxygen to the pile, and reinvigorate the composting process. Temperatures will rise after each mixing until most readily available organic material is consumed. After the pile is capped, wait 11 to 14 days before turning the mixture. However, if the temperature falls below 120 °F or rises above 180 °F, the compost pile should be aerated or mixed immediately.

Successful composting requires a specific range of particle sizes, moisture content, carbon-to-nitrogen ratio, and temperature. The following general rules apply:

▾ **Particle Size.** Particles that are too small will compact to such an extent that air movement into the pile is prevented. Material that is too large allows too much exchange of air, and so prevents the heat from building up properly. A proper mixture of size allows both air exchange and temperature buildup.

▾ **Moisture Content.** The ideal moisture content in the composting pile ranges from 40 percent to 60 percent. Too much moisture can cause the pile to become saturated, which excludes oxygen. The process then becomes anaerobic, a condition that results in offensive odors and attracts flies. Runoff from a composter that is too wet can pollute the soil or water. Too little moisture reduces microbial activity and decreases the rate of composting.

▾ **Carbon-to-Nitrogen Ratio.** Carbon and nitrogen are vital nutrients for the growth and reproduction of bacteria and fungi; therefore, the ratio of carbon to nitrogen (C:N) influences the rate at which the composting process proceeds. Conditions are most ideal for composting when the C:N ratio is between 15:1 and 35:1.

If the C:N is too high, the process slows down because it has insufficient nitrogen. This imbalance can be corrected by adding more manure or litter to the compost pile. If the C:N ratio is too low, the bacteria and fungi cannot use all of the available nitrogen, and the excess nitrogen will be converted to ammonia, resulting in unpleasant odors. This problem is fixed by adding more straw or sawdust.

More recent experience has shown, however, that composting poultry mortalities results in a partial compost. Hence, maintaining the exact carbon-to-nitrogen ratio, while important, is not critical. Many recipes now reduce or eliminate straw entirely, substituting cake, as previously noted, or even the composted product. In fact, 50 percent of the contents in the secondary bin can be input with a new batch of mortalities in the primary bin. This practice reduces the amount of compost that will need to be land applied by 50 percent.

▾ **Temperature.** The best indicator of proper biological activity in the composter is temperature. Use a probe-type 36-inch stainless steel thermometer, 0 to 250 °F, with a pointed tip to monitor temperatures within the compost pile. Optimum temperature range is 130 to 150 °F. When the temperature decreases, the general problem is that not enough oxygen is available for the bacteria and fungi. Oxygen can be replenished by turning or aerating the pile. Temperatures will rise as the composting process repeats itself.

The cycle of composting, turning, composting can be repeated as long as there is organic material available to compost and the proper moisture content and C:N ratio are present. When temperatures reach the optimum range for three days, harmful microorganisms (pathogens) and fly larvae will be destroyed. Daily recording of the temperatures in the piles is important because